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Journal of the

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

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SED RESEARCH REPORT NO. 8

ON TREATMENT OF ALKALINE SULFUR DYE WASTE WITH FLUE GAS

BY The Sanitary Engineering Research Committee, Industrial Waste Section.

From Research Data of Charles J. Beach and Malcolm G. Beach, U. S. Rubber Company, Winnsboro, South Carolina.

Acknowledgment The Sanitary Engineering Division gratefully recognizes the generosity and professional courtesy of the authors in making these research data available to the Society for review, presentation and comment by the Industrial Waste Section of the Research Committee.

Synopsis The authors describe the results obtained when treating alkaline sulfur-containing dye wastes in a jet flue gas pilot plant.

Introduction

Alkaline sulfur dye wastes are almost invariably heavily loaded with dissolved organic matter high in B.O.D. Biological treatment is usually recommended for oxidizing organic matter in this physical state. Excess alkalinity, however, often hinders the oxidation process. It is imperative that the waste be neutralized to some degree in some manner. General practice has been to neutralize with sulfuric acid or bottled carbon dioxide gas. The cost of such a preliminary conditioning operation is often prohibitive. The consulting sanitary engineer is always on the lookout for an economical, practical and effective method of reducing the pH before biological treatment. The researchers state "the idea of using one waste product of industry to treat another waste product has always interested men involved in industrial waste treatment. One such waste product is flue or stack gas, which contains from 12 to 14% carbon dioxide, and can be used to neutralize caustic solutions." The use of flue gas for treating this particular waste is two fold: first, to neutralize the excess alkalinity and, second, to strip out the hydrogen sulfide.

Note: Discussion open until March 1, 1956. Paper 1078 is part of the copyrighted Journal of the Sanitary Engineering Division of the American Society of Civil Engineers, Vol. 82, No. SA 5, October, 1956.

Character or Waste

The waste water originates from the dyeing and treating of yarn. The dyeing operations average 24% sulfur colors. The instantaneous waste discharge ranges in pH from 2 to 11 with an average of 9, has an average total solids of 3000 ppm, ranges up to 30 ppm sulfides and has an average B.O.D. of 250 ppm.

Pilot Plant

A pilot plant was constructed, using a 500 gallon steel cylindrical tank. An orifice-type head box was mounted on the wall to regulate and measure the flow of waste water to the tank. The waste water to be treated was pumped with a centrifugal pump from a retention reservoir to the head box, from here it flowed by gravity to the bottom of the tank where it was released through holes drilled in the horizontal portion of the pipe. The hot flue gas, pumped from the boiler breeching by an impeller-type blower, was released at the bottom of the tank through 1/2" holes drilled in the horizontal portion of the gas pipe. The tank was filled to about 90% of its depth and the effluent flowed out of the tank through a pipe to the drain. Waste gases were allowed to escape from the top of the tank to the breeching of an idle smoke stack. The flue gas blower delivered 58 cfm of gas to the treatment tank at a pressure of 2 psi and the influent waste flow could be varied from 3.2 to 23 gallons per minute.

Results

By varying the influent flow, the retention time was varied from 131 to 18 minutes. At a flow rate of 19 gpm (22 minutes retention) the pH adjusted to an equilibrium value of 6.4 and all of the sulfides were removed. At 20 minutes retention, 98% of the sulfides were removed and a pH of 6.6 resulted. The pilot plant was then operated at this rate for some time to gather data as to the reliability of the initial results. The results were consistent and satisfactory but the maintenance of the blower was excessive due to corrosion.

A commercial fume scrubber which operates on the aspirator principle was obtained so that the tests could be carried out on a larger scale to determine if the fume scrubber could replace the blower in the flue gas treatment plant. A 4" fume scrubber was mounted on the top of the pilot plant and the piping arranged so that 25% of the waste would pass through the 3/8" nozzle of the jet and the remaining 75% of the waste would be mixed with the treated waste in the tail pipe portion of the scrubber.

The pH reduction and sulfide removal equaled that of the blower system. In order to get better contact between the waste and the flue gas, a 3/4" nozzle was installed in the jet. This eliminated the by-pass piping that was used with the 3/8" nozzle. Using the 3/4" nozzle, 19 GPM of dye waste was handled reducing the pH from 9.0 to 6.1 and eliminating 98% of the H_2S on a pilot plant scale. The maintenance problem appears to be solved. The waste gases from the jet, in the final plant, will be introduced into the hot stack.

The effluent from the pilot plant when the jet was used was piped to the sewage plant, mixed with settled domestic sewage, and treated on a trickling filter. The results from these tests showed that the neutralized dye waste could be treated biologically.

Engineering Implications

The authors demonstrated the practicability of using flue gas to reduce the pH and scrub the sulfides out of dye waste. The advantage of such a system is obvious. Waste stack gas replaces expensive acids or bottled gas as a neutralizing agent. The resulting effluent is neutral in pH and free of sulfur in the sulfide form. It would seem probable that the waste with a pH of 6 to 7 will oxidize biologically at a faster rate than the alkaline waste. The complete removal of sulfides from the waste eliminates the possibility of these sulfur compounds becoming reduced to sulfides later on in the receiving stream. Discharge of the sulfide gases to the idle smokestack is a novel system but should be used with caution. A low stack and proper (unfavorable) meterological conditions could lead to air pollution problems.

Credit

This research report, which is one of a series of professional contributions by the Committee on Sanitary Engineering Research.

	William T. Ingram	Air Pollution
	Herman R. Amberg	Stream Pollution
	Frank S. Palocsay	Sewage
	C. H. Hull	Water
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has been prepared by the Industrial Waste Section.

Don E. Bloodgood
Ross C. McKinney
C. Fred Gurnham
Nelson L. Nemerow, Member in Charge

Journal of the
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SEDIMENTATION STUDIES

D. E. Bloodgood,[1] M. ASCE, W. J. Boegly, Jr.,[2] and C. E. Smith[3]
(Proc. Paper 1083)

SYNOPSIS

Sedimentation studies were carried out in the laboratory to substantiate Hazen's theory that sediment removal is dependent upon surface area and independent of depth. The results showed that removal of sediment was dependent upon the force of the incoming water.

This paper covers the work done on Sedimentation at Purdue University from July 1, 1949 to November 1, 1955. Funds for this project were obtained through the Federal Security Agency, Public Health Service, National Institutes of Health.

Thoughts on Sedimentation by Others

Allen Hazen(1) in 1904 made the first basic analysis of the factors affecting the settling of solid particles in water. His analysis, based on certain assumptions, showed that detention time was not a factor in the design of settling tanks, but rather that the per cent removal was dependent on the surface area of the tank, the settling properties of the solid matter, and was inversely proportional to the flow through the tank. Depth of the tank, according to the Hazen theory, had no effect on the per cent removal, indicating that a tank, no matter how shallow, will produce as good a result as a deep tank for the same flow. There seems to be no published record that he or anyone else ever confirmed his theory by experimental tests using a settling tank.

Camp(2) has pointed out that the conditions assumed in the Hazen theory do

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not exist in actual designed tanks. He presents equations and curves which take into account turbulence, bed load movement and short-circuiting and he developed formulae to state mathematically his opinions and beliefs. Camp also states that depth of tank does not alter the removal in a tank.

Ingersoll, McKee, and Brooks(3) have also studied factors affecting the design of settling tanks. They agree with the findings of Hazen and Camp that detention time and depth need not be considered in the design of settling tanks. Many design standards still call for a specific detention period.

Camp(2) also points out a method for determining the settling properties of a suspension of solid material in water. He says further that by means of a settling tube the settling velocities of the particles can be calculated and the theoretical per cent removal in an ideal tank can be determined. He did not, as far as we know, present any method for correlating settling tube results with actual settling tank results.

Even with the development of what seem to be sound theories, sedimentation tanks have been designed to give a specific retention period to settling water or sewage. It seemed desirable to make fundamental studies to obtain more information on settling tank behavior. It was, therefore, the purpose of the Purdue studies to obtain fundamental information about settling tanks.

Dobbins(4) made an experimental analysis of the mixing phenomena for which Camp(2) had developed formulae. The Dobbins tests were conducted in an unconventional settling tank.

Escritt(5) discussed the problem of inlets and suggested that the velocity head was the important factor to be taken into account when considering inlet design. He stated that the velocity head produced eddies which interfered with the settling of the particles. He visualized a zone in the tank in which the eddies produced by the influent water reduced the removal of solids in the tank.

Clifford(6) wrote that the important factor to be considered in inlet design was the kinetic energy of the influent water. He presented sketches showing the portion of the tank which was required to still the influent water at various values of kinetic energy.

Test Apparatus

A model settling tank was designed and constructed in such a manner as to be able to vary the length, width, and depth with a maximum tank size possible of 14 feet by 6 feet by 2.1 feet. The flow through the tank could be varied from 0 to 100 g.p.m. Different arrangements of influent baffles were possible. The sides of the tank were made of clear lucite so that the settling of the particles could be observed or photographed if desired. The tank as constructed is shown in Figure 1.

To prepare a uniform slurry for addition to the incoming water to the settling tank a mixing tank was constructed. The mixing tank component parts were the tank proper, an adjustable lid, an oscillating mixing grid, and an electric motor-driven crank and eccentric mechanism which operated the mixing grid. The mixing tank for slurry production is shown in Figure 2.

At the start of a series of tests dry sediment was placed in the bottom of the mixing tank. When the tank was filled with water and started in operation, the mixing grid moved up and down, suspending the upper layer of the sediment. The slurry produced in this manner was pumped to the settling tank.

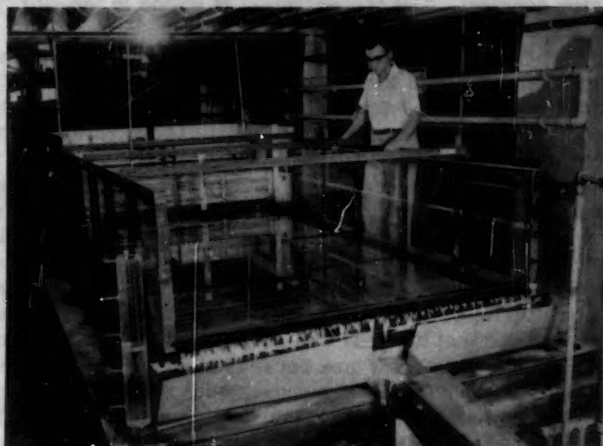


Figure 1

View of Settling Tank

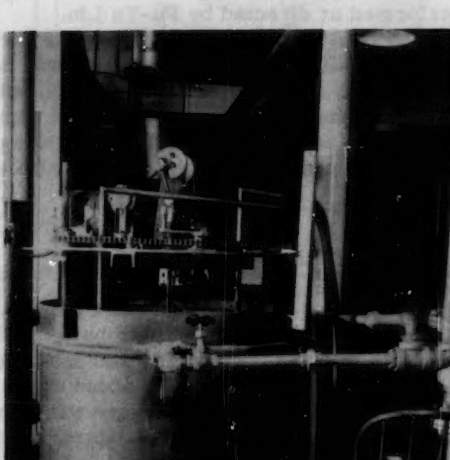


Figure 2

Mixing Tank for Slurry Production

Fresh water was continuously added to the mixing tank to keep the volume of water in the tank constant. The concentration of solids in the slurry was controlled by raising or lowering the mixing grid.

The concentration of solids in the slurry was controlled by means of spectrophotometer readings of the slurry.

All suspended solids were determined using fritted glass crucibles. A 200 ml. sample was used to determine the solids concentration in the influent and effluent of the settling tank.

The first problem encountered was the finding of a suitable sediment for the tests. Desirable properties of the sediment were: (1) uniform particle size, (2) uniform density, (3) a specific gravity within the range of 1.1 to 1.5, and (4) particles to be as nearly spherical as possible. The sediment had to be readily available and had to be inexpensive. The following materials were considered: coal; lucite powder; cement; lime; rice flour; and activated carbon. Chapman(7) found that the coal was undesirable. None of the other materials were ever used in the test tank because preliminary tests showed them to be unsatisfactory. It was then suggested that Celite, a diatomaceous silica sold by the Johns-Manville Company, might prove to be a suitable sediment. Settling tests(8) proved that it was suitable and it was used as the sediment in all studies reported in this paper.

Preliminary Tests

Construction of the mixing and settling tanks was started in 1949 and most of this work was performed or directed by Pu-Yu Liu.

Chapman(7) made the first settling tests and he used finely divided coal sediment that had been classified in a wind tunnel. It was hoped that the coal sediment could be reused for a number of settling tests, but it was found that the finer particles were washed out in the tests and the remaining particles of sediment did not have the settling characteristics of the original mixture. It was an impossible task to process enough coal so that it could be used only once.

Baffled Tank Studies

In the tests conducted by Smith(8) the tank was equipped with two baffles at the head end. A plan of the lay-out is shown in Figure 3. The two baffles were made of wooden lath that ran horizontally and had about 1/4-inch spaces between each lath. The water and slurry were added at the very head end of the tank so that there was complete mixing. There was almost ideal distribution of entering water with sediment after the mixture had passed through the two baffles.

In the baffling and stilling of the influent to the settling compartment there was time for some sedimentation, so in order to determine the solids concentration of the material entering the settling compartment it was necessary to take samples at the downstream side of the second baffle. This sampling was accomplished by drawing liquid through tubing placed at several locations. The sediment used was Celite 545. Four tank sizes were used in 35 separate tests. The tank sizes used were:

1) 11.5 feet x 6.0 feet x 2.1 feet
2) 11.5 feet x 4.0 feet x 2.1 feet

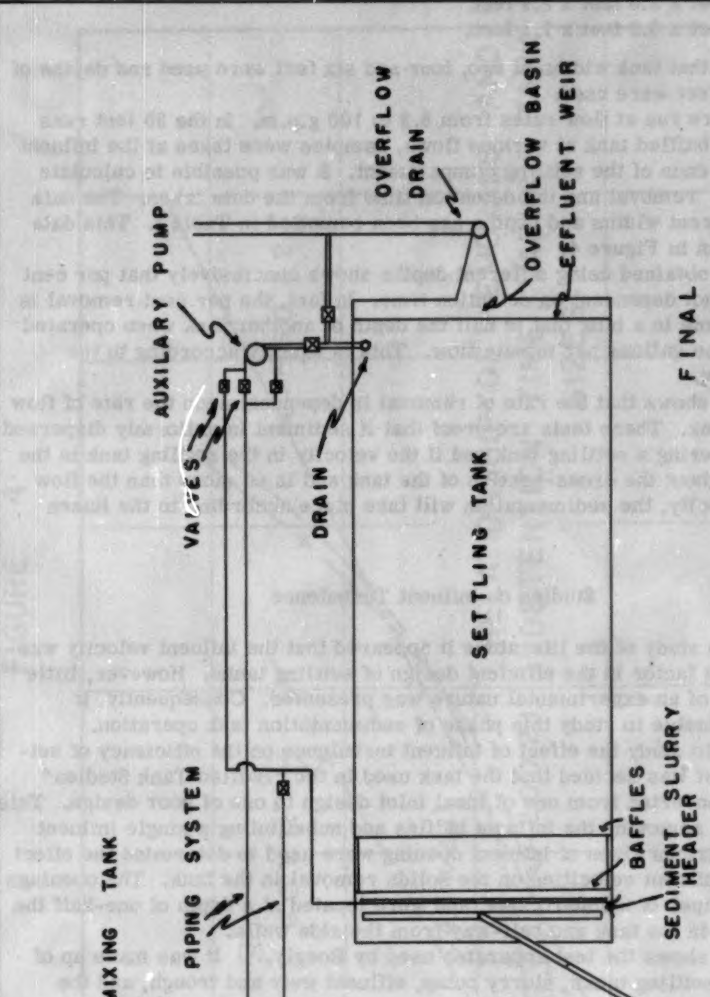


FIGURE 3
FINAL PLAN LAYOUT OF EXPERIMENTAL APPARATUS

3) 11.5 feet x 2.0 feet x 2.1 feet
4) 11.5 feet x 6.0 feet x 1.1 feet.

This means that tank widths of two, four and six feet were used and depths of 1.1 and 2.1 feet were used.

Tests were run at flow rates from 8.3 to 100 g.p.m. In the 35 test runs made in the baffled tank at various flows, samples were taken at the influent and effluent ends of the settling compartment. It was possible to calculate the per cent removal and the detention time from the data taken. The data for the different widths and depths has been compiled in Table I. This data is also shown in Figure 4.

The data obtained using different depths shows conclusively that per cent removal is not dependent on detention time. In fact, the per cent removal is about the same in a tank that is half the depth of another tank when operated with the same gallons per minute flow. This is exactly according to the Hazen theory.

Figure 5 shows that the rate of removal is dependent upon the rate of flow through a tank. These tests are proof that if sediment is uniformly dispersed in water entering a settling tank and if the velocity in the settling tank is the same throughout the cross-section of the tank and is no more than the flow through velocity, the sedimentation will take place according to the Hazen theory.

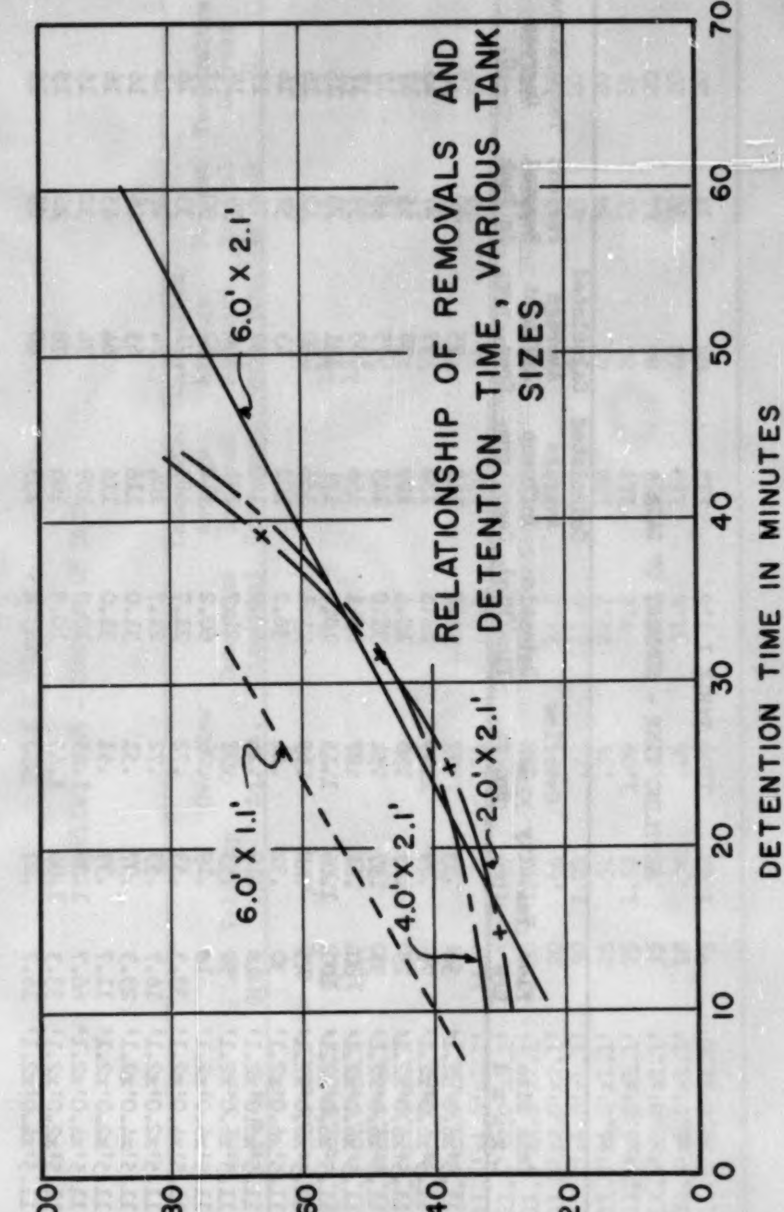
Studies on Influent Turbulence

From the study of the literature it appeared that the influent velocity was an important factor in the efficient design of settling tanks. However, little information of an experimental nature was presented. Consequently, it seemed advisable to study this phase of sedimentation tank operation.

In order to study the effect of influent turbulence on the efficiency of settling tanks, it was decided that the tank used in the "Baffled Tank Studies" should be converted from one of ideal inlet design to one of poor design. This was done by removing the influent baffles and substituting a single influent opening. Various sizes of influent opening were used to determine the effect of various influent velocities on the solids removal in the tank. The openings used were pipes of standard size, and were located at a depth of one-half the water depth in the tank and half-way from the side walls.

Figure 6 shows the test apparatus used by Boegly.[9] It was made up of mixing and settling tanks, slurry pump, effluent weir and trough, and the single influent opening. No baffling was provided. A series of 22 tests was made with this tank set-up using three sizes of influent opening. The cross-sectional areas of these openings were: 0.0142, 0.00601, and 0.0021 square feet. Tests were run at rates of flow from 7 to 80 gpm. Celite 545 was also used as the sediment in these tests. The results of the 22 tests are presented in Table II. When the rates of removal were plotted against the corresponding rates of flow (Figure 7) three curves resulted, one for each different size of influent opening. The influent velocity was then plotted against the corresponding removal in the tank, and again three sets of curves resulted (Figure 8). It was noted that for the same rate of flow a greater per cent removal was obtained with the largest size of opening, whereas for the same velocity the greatest per cent removal was obtained with the smallest opening (See Figures 7 and 8). Thus it was felt that there was some relationship between

FIGURE 4



RELATIONSHIP OF REMOVALS AND DETENTION TIME, VARIOUS TANK SIZES

TABLE I

SETTLING TANK - SUMMARY OF DATA

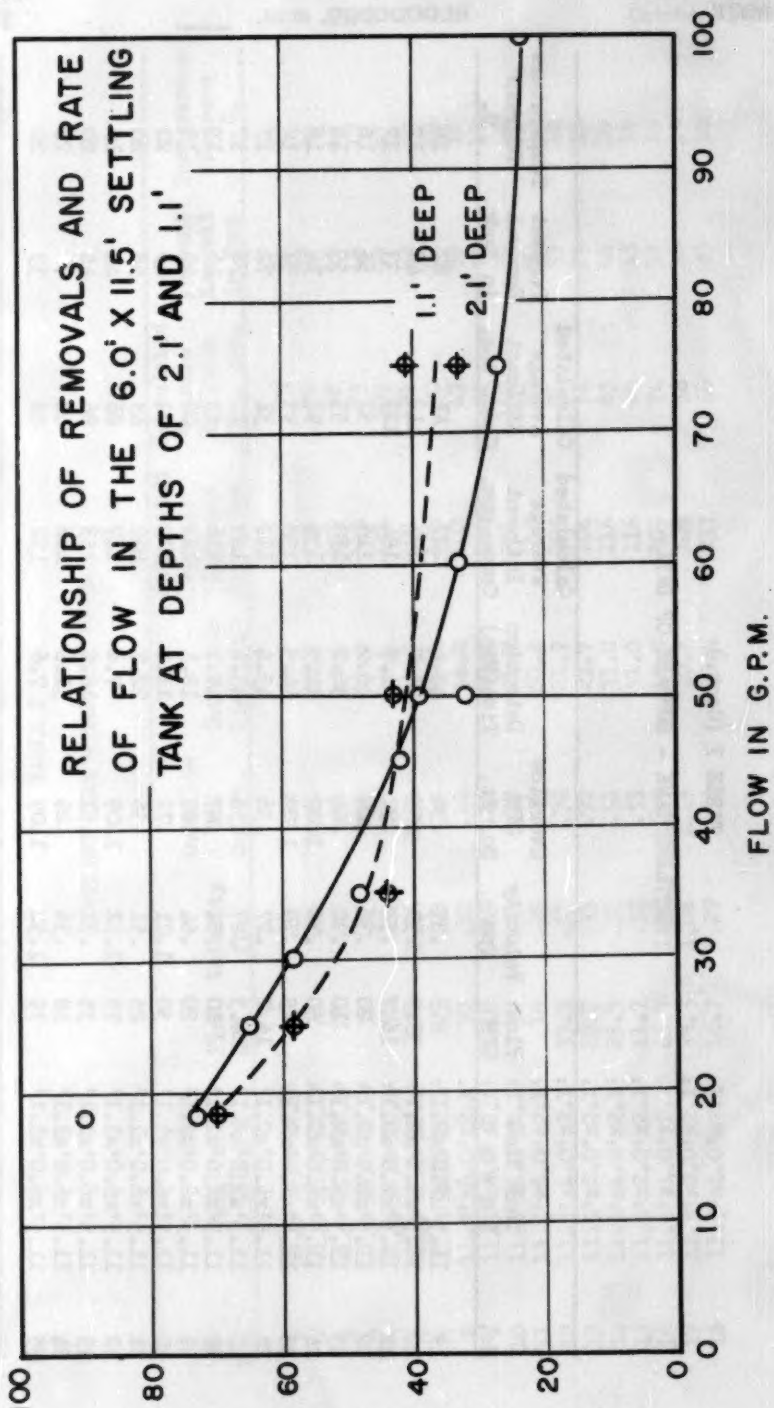
No.	Tank Size L x w x d	Flow GPM	Velocity fpm	Overflow GPM Sq. ft.	Detention Time(Min)	Calculated Average Influent Conc. ppm.	Calculated Average Effluent Conc. ppm.	Percent Removal in Tank	Temperature Degrees C.
1	11.5'x6.0'x2.1'	50	.53	.72	21.7	110	75	32	17
2	11.5'x6.0'x2.1'	75	.79	1.09	14.5	136	99	27	15
3	11.5'x6.0'x2.1'	25	.27	.36	43.4	109	38	65	17
4	11.5'x6.0'x2.1'	35	.37	.51	31.0	145	75	48	17
5	11.5'x6.0'x2.1'	60	.64	.87	18.1	156	105	33	17
6	11.5'x6.0'x2.1'	100	1.06	1.45	10.8	171	131	23	15
7	11.5'x6.0'x2.1'	45	.48	.65	24.1	156	90	42	16
8	11.5'x6.0'x2.1'	30	.32	.44	36.2	102	43	58	16
9	11.5'x6.0'x2.1'	18	.19	.26	60.2	120	32	73	17
10	11.5'x6.0'x2.1'	50	.53	.72	21.7	231	140	39	17
11	11.5'x6.0'x2.1'	18	.19	.26	60.2	318	32	90	17
12	11.5'x4.0'x2.1'	33.3	.53	.72	21.7	105	71	33	16
13	11.5'x2.0'x2.1'	16.7	.53	.72	21.7	104	74	29	16
14	11.5'x4.0'x2.1'	23.3	.37	.51	31.0	116	63	46	16
15	11.5'x2.0'x2.1'	11.7	.37	.51	31.0	116	64	45	16
16	11.5'x4.0'x2.1'	66.7	1.06	1.45	10.8	109	74	32	15
17	11.5'x2.0'x2.1'	33.3	1.06	1.45	10.8	106	78	26	15
18	11.5'x4.0'x2.1'	16.7	.27	.36	43.4	233	40	83	16

TABLE I (Cont.)

SETTLING TANK - SUMMARY OF DATA

No.	Tank Size L x w x d	Flow GPM	Velocity fpm	Overflow GPM Sq. Ft.	Detention Time(Min)	Calculated Average Influent Conc. ppm.	Calculated Average Effluent Conc. ppm.	Percent Removal in Tank	Temperature Degrees C.
19	11.5'x2.0'x2.1'	8.3	.27	.36	43.4	227	41	82	16
20	11.5'x4.0'x2.1'	33.3	.53	.53	21.7	197	112	43	17
21	11.5'x2.0'x2.1'	16.7	.53	.72	21.7	184	123	33	17
22	11.5'x4.0'x2.1'	20	.32	.44	36.2	115	52	55	18
23	11.5'x2.0'x2.1'	10	.32	.44	36.2	130	53	59	18
24	11.5'x4.0'x2.1'	50	.79	1.09	14.5	139	92	34	18
25	11.5'x2.0'x2.1'	25	.79	1.09	14.5	138	93	33	18
26	11.5'x4.0'x2.1'	16.7	.27	.36	43.4	110	31	72	17
27	11.5'x2.0'x2.1'	8.3	.27	.36	43.4	123	27	78	17
28	11.5'x4.0'x2.1'	40	.64	.87	18.1	116	63	46	18
29	11.5'x2.0'x2.1'	20	.64	.87	18.1	122	66	46	18
30	11.5'x6.0'x1.1'	50	1.01	.72	11.4	127	72	43	20
31	11.5'x6.0'x1.1'	25	.51	.36	22.7	102	43	58	20
32	11.5'x6.0'x1.1'	75	1.52	1.09	7.6	147	86	41	19
33	11.5'x6.0'x1.1'	35	.71	.51	16.2	153	86	44	20
34	11.5'x6.0'x1.1'	18	.36	.26	31.6	162	48	70	20
35	11.5'x6.0'x1.1'	75	1.52	1.09	7.6	132	88	33	20

FIGURE 5


RELATIONSHIP OF REMOVALS AND RATE OF FLOW IN THE 6.0' X 11.5' SETTLING TANK AT DEPTHS OF 2.1' AND 1.1'
1.1' DEEP
2.1' DEEP
PERCENT REMOVAL
0
20
40
60
80
100
FLOW IN G.P.M.
0
10
20
30
40
50
60
70
80
90
100

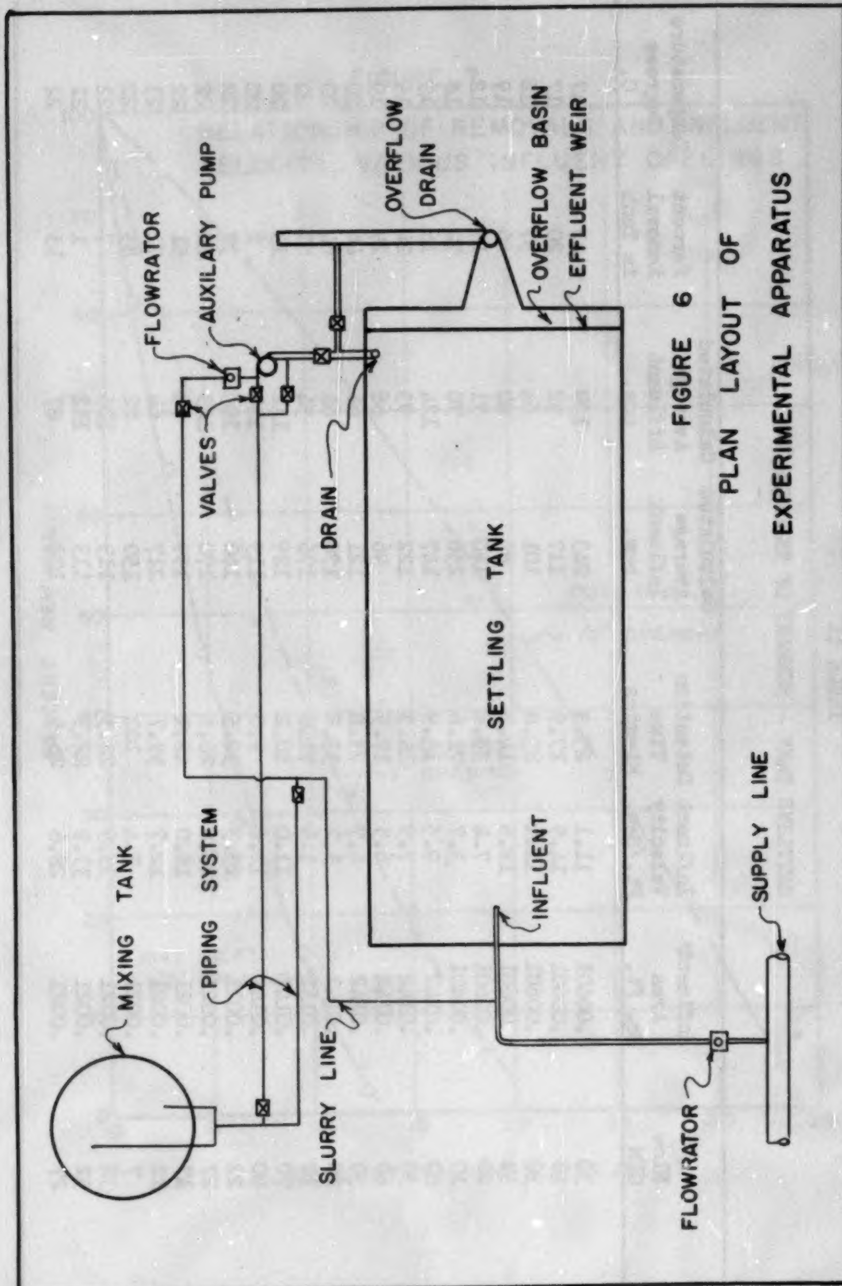


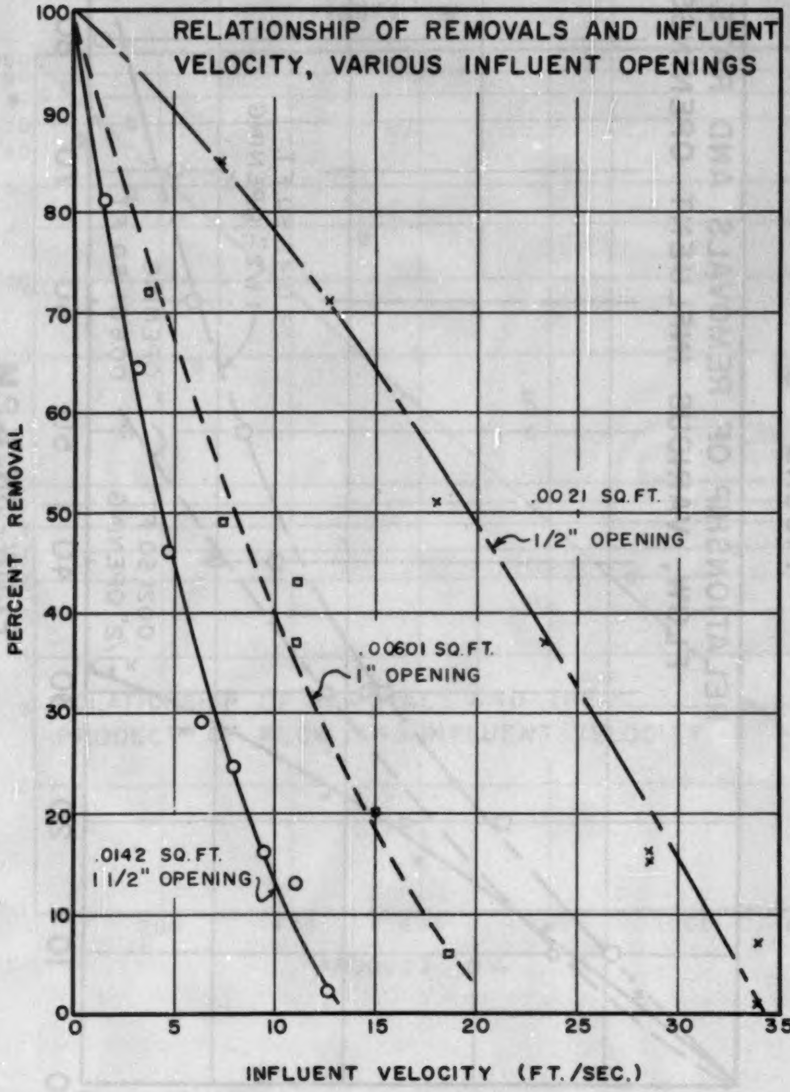
FIGURE 6
PLAN LAYOUT OF
EXPERIMENTAL APPARATUS

TABLE II

SETTLING TANK - SUMMARY OF RESULTS

Run No.	Flow GPM	Influent Area Sq. Ft.	Influent Velocity Ft./Sec.	Detention Time Minutes	Calculated Average Influent ppm.	Calculated Average Effluent ppm.	Percent Removal in Tank	Temperature Degrees C.
1	30	.00601	11.1	23.8	243	139	43	17
2	40	.00601	14.9	17.9	117	92	20	17
3	30	.00601	11.1	23.8	101	64	37	18
4	50	.00601	18.6	14.3	85	80	6	19
5	20	.00601	7.4	35.8	140	71	49	18
6	10	.00601	3.7	71.6	256	70	72	18
7	60	.0142	9.5	11.9	147	124	16	19
8	50	.0142	7.9	14.3	122	93	24	19
9	40	.0142	6.3	17.9	96	68	29	19
10	30	.0142	4.7	23.8	121	66	46	20
11	20	.0142	3.2	35.8	170	61	64	20
12	10	.0142	1.6	71.6	176	34	81	20
13	70	.0142	11.0	10.2	129	112	13	20
14	80	.0142	12.6	9.0	119	117	2	20
15	22	.0021	23.3	32.5	160	105	37	22
16	27	.0021	28.6	26.5	170	143	16	22
17	17	.0021	18.0	42.2	199	98	51	22
18	12	.0021	12.7	59.7	217	64	71	23
19	7	.0021	7.4	102	150	22	85	22
20	32	.0021	33.9	22.3	113	105	7	22
21	32	.0021	33.9	22.3	113	112	1	22
22	27	.0021	28.6	26.5	102	87	15	22

FIGURE 7


RELATIONSHIP OF REMOVALS AND INFLUENT
VELOCITY, VARIOUS INFLUENT OPENINGS
PERCENT REMOVAL
INFLUENT VELOCITY (FT./SEC.)
.0021 SQ.FT.
1/2" OPENING
.00601 SQ.FT.
1" OPENING
.0142 SQ.FT.
1 1/2" OPENING
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35

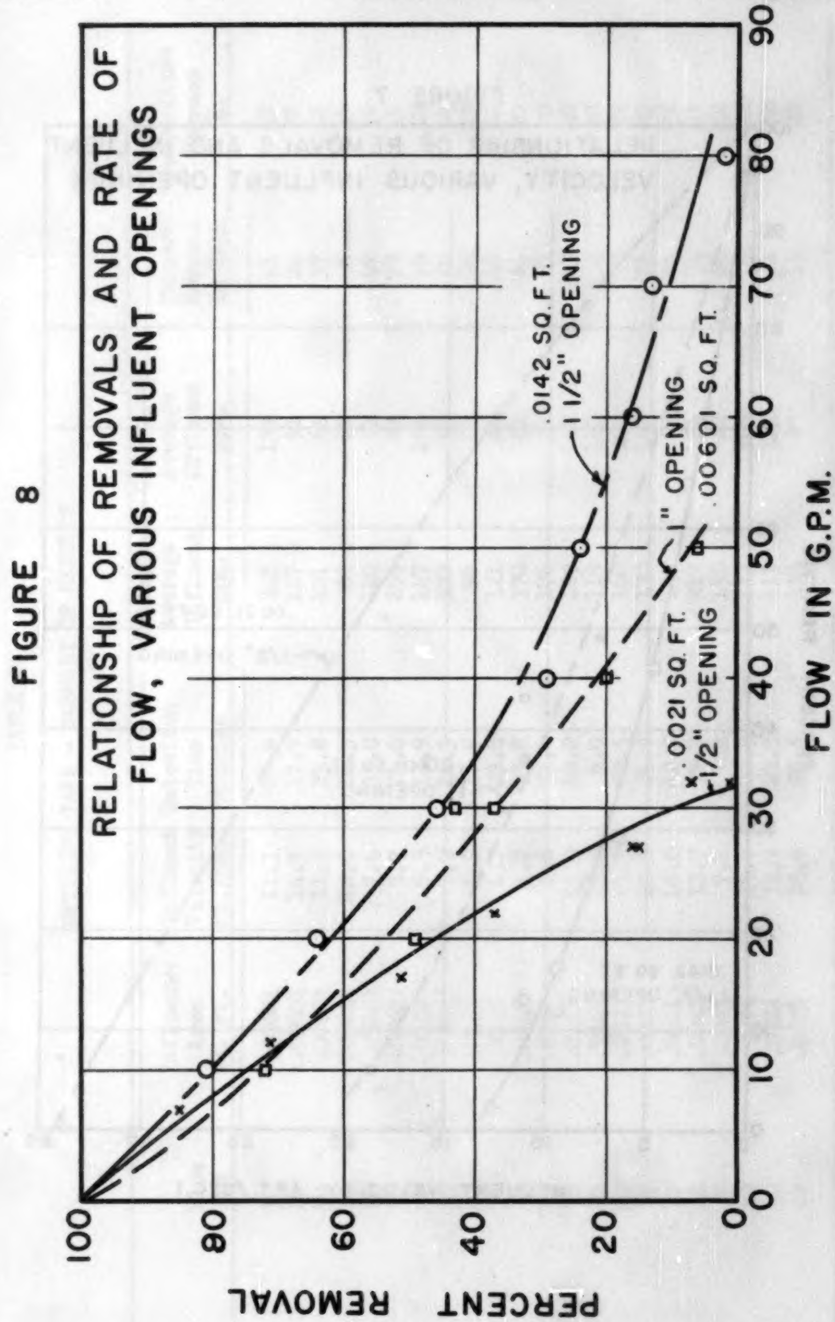
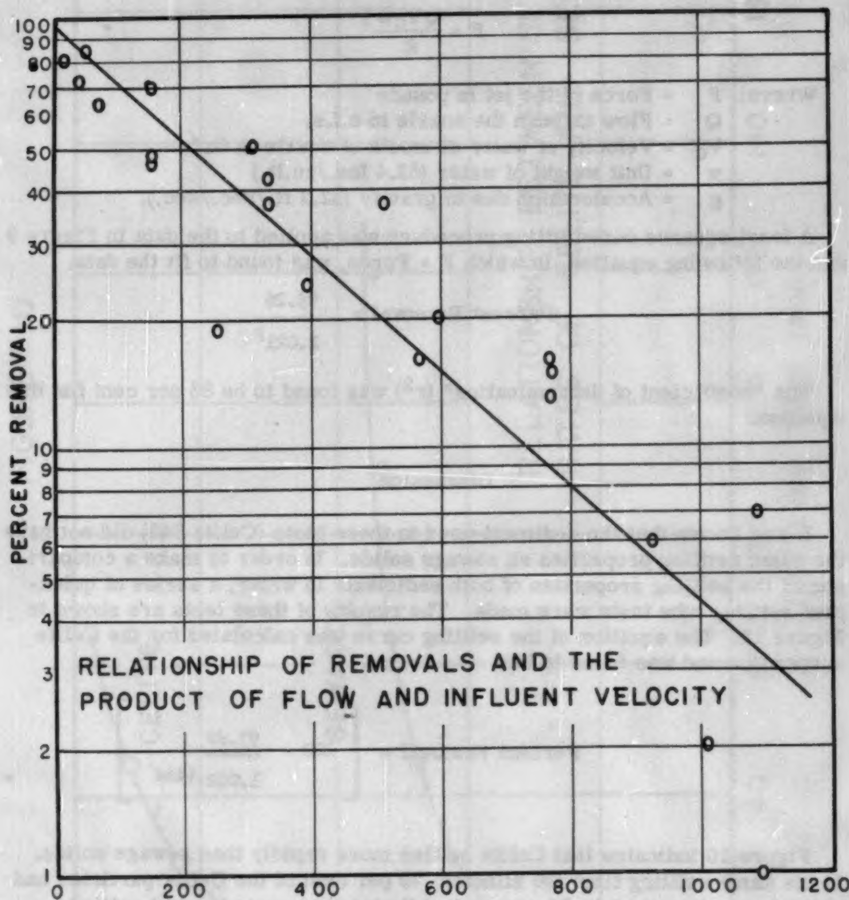


FIGURE 8

RELATIONSHIP OF REMOVALS AND RATE OF FLOW, VARIOUS INFLUENT OPENINGS

FIGURE 9


RELATIONSHIP OF REMOVALS AND THE
PRODUCT OF FLOW AND INFLUENT VELOCITY
PERCENT REMOVAL
PRODUCT QV.
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0
200
400
600
800
1000
1200

the flow and the influent velocity. When the product of flow and influent velocity was plotted against the removal obtained in the tank only one curve was found to exist (Figure 9). The product QV_o was found to be similar to the expression for the force of a jet of water striking a flat plate at a right angle to the direction of flow. This expression given by Gibson(10) is:

$$F = \frac{QV_o w}{g}.$$

Where: F = Force of the jet in pounds
Q = Flow through the nozzle in c.f.s.
V_o = Velocity of water at mouth of nozzle in ft./sec.
w = Unit weight of water (62.4 lbs./cu.ft.)
g = Acceleration due to gravity (32.2 ft./sec./sec.).

A least squares curve fitting procedure was applied to the data in Figure 9 and the following equation, in which F = Force, was found to fit the data.

$$\text{Percent Removal} = \frac{95.26}{2.021^F}$$

The "coefficient of determination" (r^2) was found to be 85 per cent for this equation.

Discussion

It was known that the sediment used in these tests (Celite 545) did not have the same settling properties as sewage solids. In order to make a comparison of the settling properties of both sediments in water, a series of quiescent settling tube tests were made. The results of these tests are shown in Figure 10. The equation of the settling curve was calculated for the Celite suspension and was found to be:

$$\text{Percent removal} = \left[100 - \frac{97.82}{1.062^{\text{time}}}\right]$$

Figure 10 indicates that Celite settles more rapidly than sewage solids. In the same settling time (20 minutes) 70 per cent of the Celite particles had settled out whereas only 34 per cent of the sewage particles had settled. Since the settling curve for sewage can be expected to be different for each sewage it was not thought worthwhile to obtain a mathematical relationship between the sewage and Celite settling properties.

Knowing the settling depth, the per cent removals, and the time to get the various per cent removals, it is possible to calculate a settling velocity distribution curve for the Celite suspension by the Camp(2) procedure. The settling velocity distribution curve for Celite is presented in Figure 11. From this curve the per cent of particles settling at a velocity, v, or less can be obtained. The median settling velocity (velocity at which 50 per cent settled with a velocity equal to or less than that velocity) was found to be 0.1002 ft./min. for Celite 545.

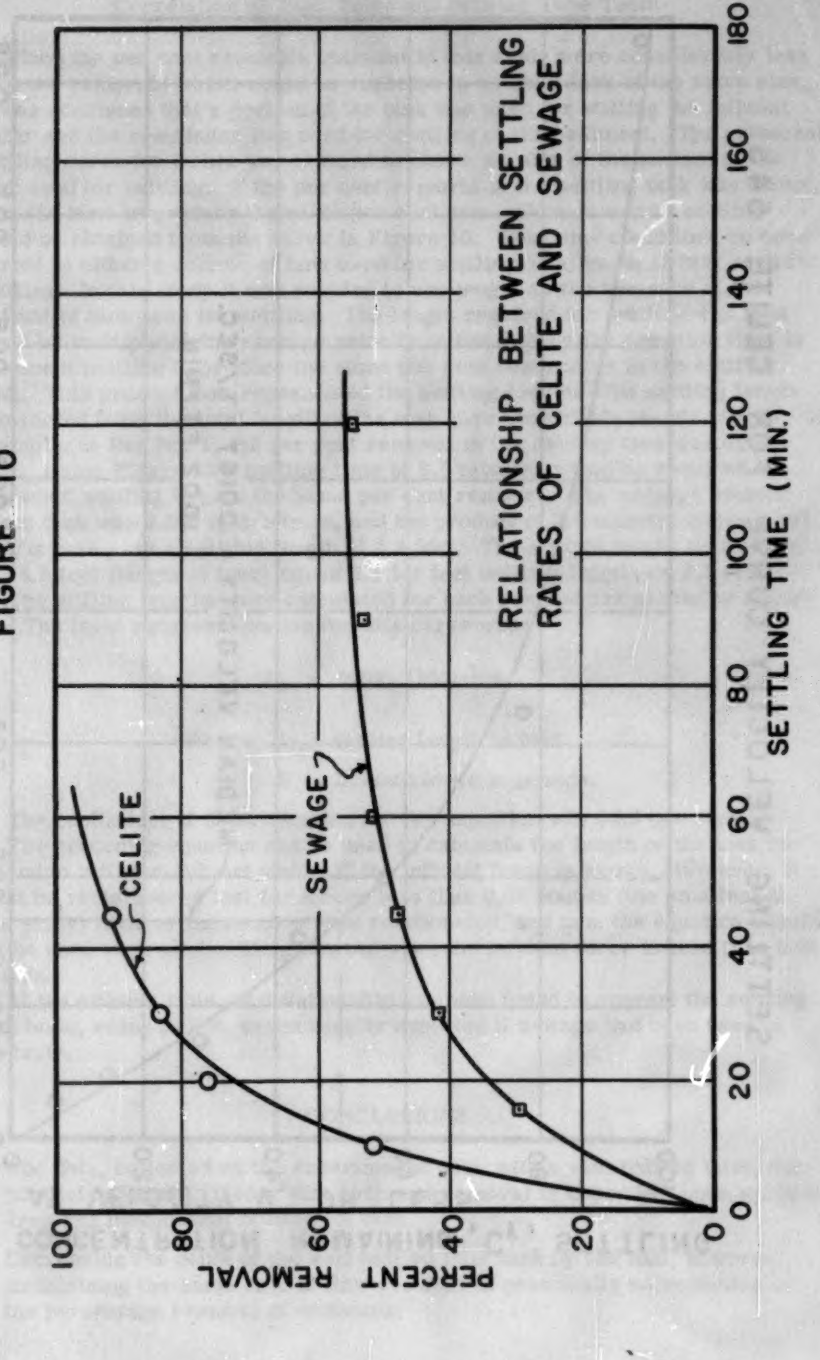
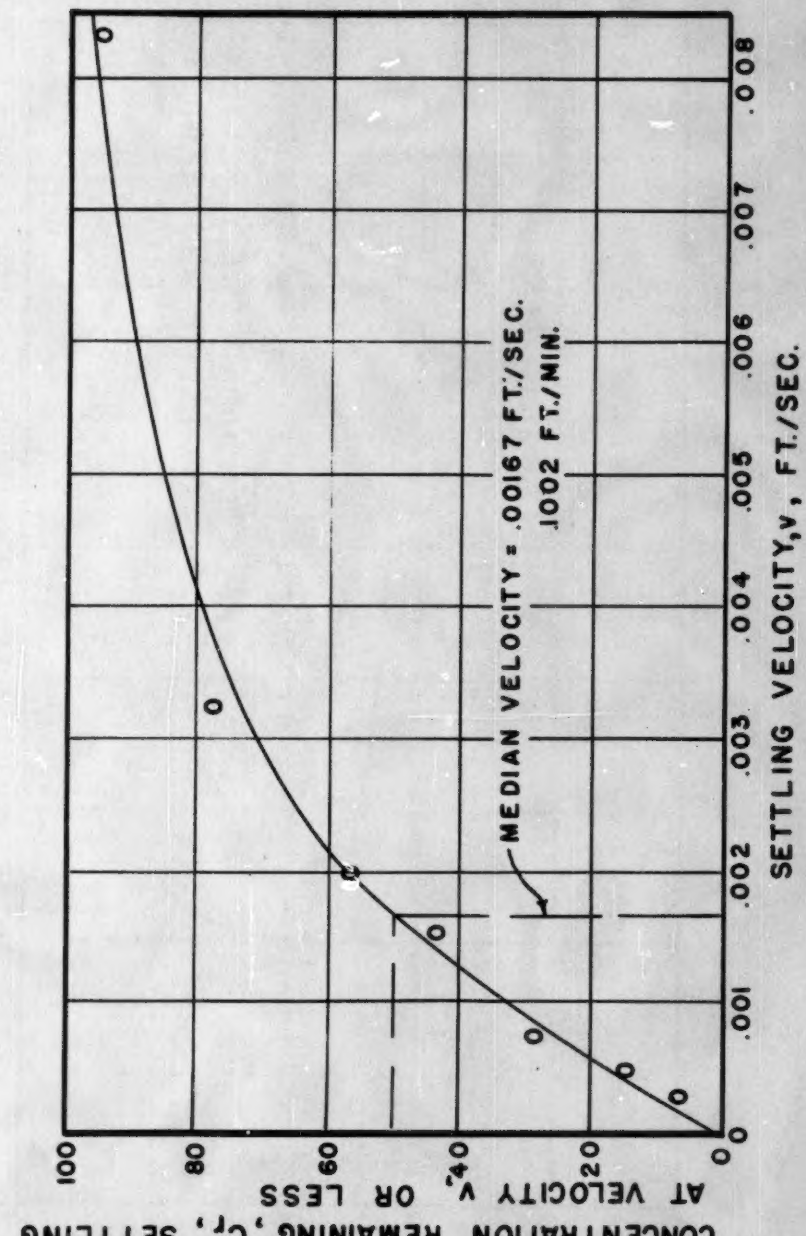

RELATIONSHIP BETWEEN SETTLING
RATES OF CELITE AND SEWAGE
CELITE
SEWAGE
PERCENT REMOVAL
0
20
40
60
80
100
SETTLING TIME (MIN.)
0
20
40
60
80
100
120
140
160
180

FIGURE 10

FIGURE 11

SETTLING VELOCITY CURVE FOR CELITE 545



Correlation of Tank Tests and Settling Tube Tests

Since the per cent removals obtained in this study were considerably less than the removals which would be expected in an ideal tank of the same size, it was concluded that a portion of the tank was used for stilling the influent water and the remainder was used for settling of the sediment. The quiescent settling curve for Celite was utilized to obtain an idea of the portion of the tank used for settling. If the per cent removal in the settling tank was known, then the time to produce the same per cent removal in quiescent settling could be obtained from the curve in Figure 10. This time could then be converted to either a volume of tank used for settling or a length of tank used for settling. In this study it was decided to use length as the measure of the amount of tank used for settling. The length required for settling was then found by multiplying the average velocity in the tank by the detention time in quiescent settling to produce the same per cent removal as in the settling tank. This product then represented the settling length. The settling length subtracted from the total length of the tank gave the stilling length. As an example, in Run No. 1, the per cent removal in the settling tank was 43 per cent. Using Figure 10 a settling time of 9.0 minutes would be required in quiescent settling to give the same per cent removal. The average velocity in the tank was 0.609 feet/minute, and the product of 9.0 minutes times 0.609 feet/minute gave a settling length of 5.4 feet. The stilling length would then be 14.5 feet (length of tank) minus the 5.4 feet settling length, or 9.1 feet.

The stilling lengths were calculated for each run and are plotted in Figure 12. The least squares equation for this curve was:

$$L_s = 7.97 \ (10F)^{.124} .$$

Where: L_s = Stilling length in feet

F = Influent force in pounds.

The coefficient of determination for this equation was 65.3 per cent.

The preceding equation can be used to calculate the length of the tank required to still the influent water, if the influent force is known. However, it must be remembered that for forces less than 0.01 pounds (the smallest in this study) little is known about this relationship, and thus the equation should not be used to predict stilling lengths when the influent force is less than 0.01 pounds.

At the present time, no relationship has been found to convert the settling tank tests, using Celite, to the results expected if sewage had been used in the tests.

CONCLUSIONS

1) The data, collected on the experimental tank with a well baffled inlet, substantiates Hazen's theory that sediment removal is dependent upon surface area and independent of depth of tank.

2) Decreasing the depth of the well baffled inlet tank by one half, however, maintaining the same rate of flow resulted in practically no reduction of the percentage removal of sediment.

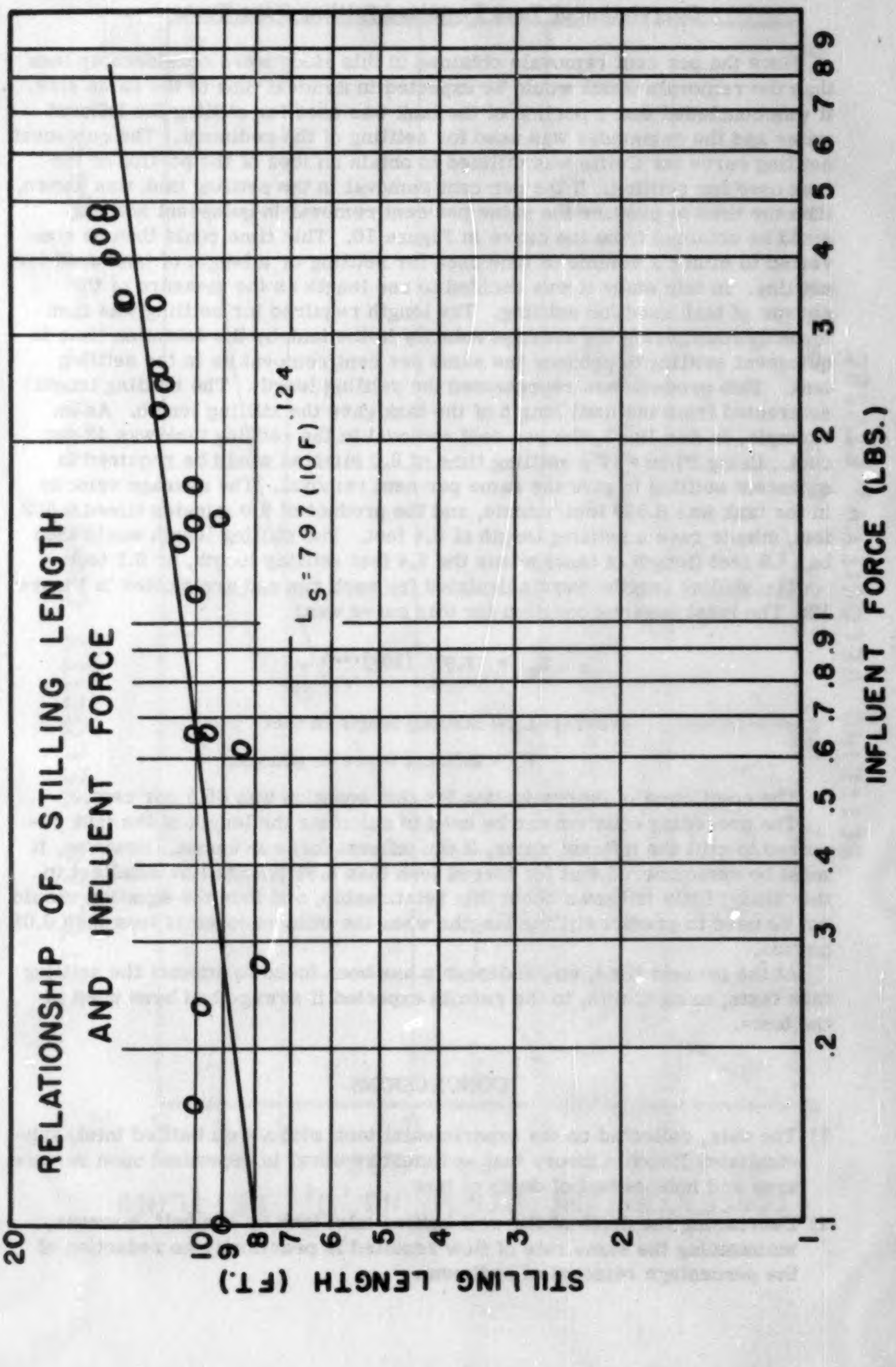

RELATIONSHIP OF STILLING LENGTH
AND INFLUENT FORCE
S = 7.97 (IOF) .124
STILLING LENGTH (FT.)
INFLUENT FORCE (LBS.)
20
10
9
8
7
6
5
4
3
2
1
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
2
3
4
5
6
7
8
9

FIGURE 12

3) The percentage removal, in the unbaffled single inlet tank, was found to be dependent on the force of the incoming water.

4) The relationship between per cent removal and force(F) was found to be

$$\text{Per cent Removal} = \frac{95.26}{2.021^{F}}$$

5) A relationship between length of tank required for stilling and influent force(F) for the experimental tank was found to be

$$\text{Stilling length} = 7.97\ (10F)^{.124}.$$

ACKNOWLEDGMENT

Preliminary research was done by Pu-Yu Liu, Howard B. Brown and H. E. Chapman. Their efforts are acknowledged and appreciated.

BIBLIOGRAPHY

1. Hazen, A., "On Sedimentation," TRANSACTIONS, ASCE, Volume LIII, (1904).
2. Camp, T. R., "Sedimentation and the Design of Settling Tanks," PROCEEDINGS, ASCE, Vol. 71, (1945) pp. 445-486.
3. Ingersoll, A. C., McKee, J. R., and Brooks, N. H., "Fundamental Concepts of Rectangular Settling Tanks," PROCEEDINGS, ASCE, Vol. 81, Separate No. 590 (1955).
4. Dobbins, W. E., "Effect of Turbulence on Sedimentation," TRANSACTIONS, ASCE, Vol. 109, (1944) pp. 629-678.
5. Escritt, L. B., "English Design of Sedimentation Tanks," SEWAGE WORKS ENGINEERING AND MUNICIPAL SANITATION, Vol. 17, No. 9 (Sept. 1946), 459-461.
6. Clifford, W., "Flow of Sewage Through a sewage Works in Relation to the Settlement of Suspended Solids," JOURNAL OF THE ROYAL SANITARY INSTITUTE, Vol. 52 (Mar. 1932), p. 407.
7. Chapman, H. E., AN INVESTIGATION OF THE FUNDAMENTAL THEORIES OF SEDIMENTATION IN A TANK, Thesis, Purdue University, 1951.
8. Smith, C. E., AN INVESTIGATION OF THE EFFECT OF VARYING THE WIDTH AND DEPTH OF A SEDIMENTATION TANK, Thesis, Purdue University, 1952.
9. Boegly, W. J., A STUDY OF THE EFFECT OF A SINGLE INFLUENT OPENING ON SEDIMENTATION IN A TANK, Thesis, Purdue University, 1956.
10. Gibson, A. H., "Hydraulics and Its Applications," Constable and Company, Ltd., London, Fourth Edition, 1942, p. 368.

1) For percentage removal in the settling sample laboratory, ... depending on the nature of the incoming water.

2) The relationship between per cent removal and Froude[4] was found to be:

$$\text{Per cent Removal} = \frac{\ldots}{\ldots}$$

3) A relationship between length of tank required for settling and Froude number for the experimental tank was found to be:

$$\text{Settling length} = 7.27\,(\text{Fr})^{-1/4}$$

ACKNOWLEDGMENT

Preliminary research was done by F. ... Lee, Howard M. Brown and H. E. Chapman. Their efforts are acknowledged and appreciated.

BIBLIOGRAPHY

1. Hazen, A., "On Sedimentation," TRANSACTIONS, ASCE, Volume LIII, (1904).

2. Camp, T. R., "Sedimentation and the Design of Settling Tanks," PROCEEDINGS, ASCE, Vol. 71, (1945) pp. 445-486.

3. Ingersoll, A. C., McKee, J. E., and Brooks, N. H., "Fundamental Concepts of Rectangular Settling Tanks," PROCEEDINGS, ASCE, Vol. 81, Separate No. 590 (1955).

4. Dobbins, W. E., "Effect of Turbulence on Sedimentation," TRANSACTIONS, ASCE, Vol. 109, (1944) pp. 629-678.

5. Kalinske, A. A., "Hydraulic Design of Sedimentation Tanks," SEWAGE WORKS ENGINEERING AND MUNICIPAL SANITATION, Vol. 17, No. 9 (Sept. 1946), 460-461.

6. Clifford, W., "Flow of Sewage Through a Sewage Works in Relation to the Settlement of Suspended Solids," JOURNAL OF THE ROYAL SANITARY INSTITUTE, Vol. 52 (Nov. 1931), p. 405.

7. Chapman, H. E., AN INVESTIGATION OF THE FUNDAMENTAL THEORIES OF SEDIMENTATION IN A TANK, Thesis, Purdue University, 1951.

8. Smith, C. E., AN INVESTIGATION OF THE EFFECTS OF VARYING THE WIDTH AND DEPTH OF A SEDIMENTATION TANK, Thesis, Purdue University, 1952.

9. Rowley, W. J., A STUDY OF THE EFFECT OF A SINGLE INFLUENT OPENING ON SEDIMENTATION IN A TANK, Thesis, Purdue University, 1956.

10. Gibson, A. H., Hydraulics and Its Applications, Constable and Company, Ltd., London, Fourth Edition, 1947, p. 395.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

AN IMPROVED DILUTION METHOD FOR FLOW MEASUREMENTS

W. A. Cawley[1] J.M. ASCE and J. W. Woods[2]
(Proc. Paper 1084)

SUMMARY

A procedure for measuring the flow in sewers containing industrial wastes by a manganese dilution method is outlined. An inexpensive technical grade of manganous sulphate was injected into the sewers and the degree of dilution determined quantitatively by flame spectrophotometric analysis. It is felt that this approach provides an accurate and relatively simple method for use with industrial wastes.

INTRODUCTION

The problem of measuring the flow in a sewer becomes involved when the physical construction of the sewer or the presence of industrial wastes adversely affects the use of the more common measuring devices. This is intensified when the classic chloride dilution method proves impractical due to high levels of chloride or other interfering ions in the industrial wastes.

An attempt to solve a problem of this type resolved itself into one of finding an accurate and rapid quantitative determination which could be used as the basis for a dilution method for flow determination. This approach required that the determination be for an ion which was not present in the waste in an appreciable concentration and which could easily and economically be introduced into the sewers. Experimentation with colorimetric methods proved unsatisfactory because the procedures were too time-consuming for practical application in determining flow. The literature indicated that flame spectrophotometric analysis might be applicable to this type problem. Experimentation with flame photometry established that a technical grade manganous sulphate could be used as a trace element. With this information the following method was developed.

Note: Discussion open until March 1, 1956. Paper 1084 is part of the copyrighted Journal of the Sanitary Engineering Division of the American Society of Civil Engineers, Vol. 82, No. SA 5, October, 1956.

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2. Senior Analytical Chemist, Rayonier Inc., Jesup, Ga.

Method

The feed solution was prepared in a fifty-five gallon drum for injection into the sewer with an air-driven barrel pump of the type used to transfer petroleum products. Feed flow rates were measured with a rotometer connected to the discharge of the pump. The quantity of feed solution used was measured with the calibration curves developed for the barrels. Approximately fifty gallons of feed solution containing 100 pounds of manganous sulphate (32% Manganese) were prepared for each set of measurements. A feed injection rate was used which would give a minimum concentration of 100 ppm as manganese at the points where the flow was to be measured. Experience indicated that five samples from the sewer at approximately one minute intervals and one sample of the feed solution provided sufficient data to produce results with the degree of accuracy desired.

Samples obtained in the field were filtered to eliminate material which might clog the aspirator of the flame photometer. After filtration the samples were read directly using the flame attachment of the Beckman Model B Spectrophotometer with the following settings:

Wave length	403.4 millimicrons
Slit width	0.6 millimeters
Sensitivity	2
H_2 gas pressure	4.5 pounds
O_2 gas pressure	10.0 pounds

The results obtained were compared to standards made up by diluting reagent grade $MnSO_4.H_2O$ with filtered waste, thus closely simulating any background interferences. From the readings obtained with these standards, calibration curves were developed converting percent transmittance to ppm manganese. By bracketing the unknowns with standards and using the interpolation formula shown below the calibration curves were checked.

$$\frac{(a-b)\ (e-d)}{(c-d)} + b = \text{ppm in unknown sample} \qquad (1)$$

where a ppm high standard
b ppm low standard
c percent transmittance of a (high standard)
d percent transmittance of b (low standard)
e percent transmittance of unknown

For example the concentration of the trace element in a sample for which the following data was obtained would be calculated as

Concentration of upper standard = 75 ppm = a
Concentration of lower standard = 50 ppm = b
Transmission of upper standard = 85% = c
Transmission of lower standard = 45% = d
Transmission of unknown = 81% = c
Substituting into (1) gives

$$\frac{(75-50)\ (81-45)}{85-45} + 50 = 72.5 \text{ ppm as concentration in unknown.}$$

The data collected was substituted in the following formula to obtain the flow in the sewer:

$$\frac{(p \times m)}{(t \times b)} = Q \qquad (2)$$

where p = feed used in gallons
m = concentration of manganese in feed used in ppm.
t = time in minutes feed was added to sewer
b = average concentration of manganese in sewer samples in ppm.
Q = flow in gallons per minute

This formula is a concentration into a single formula of the normal approach to such a problem and is arrived at as follows:

$$\frac{p}{t} = \text{gallons per minute of feed used}$$

$$\frac{m \times 8.34}{10^6} = \text{pounds per gallon of manganese in the feed}$$

$$\frac{p}{t} \times \frac{m \times 8.34}{10^6} = \frac{p \times m}{t} \times \frac{8.34}{10^6} = \text{pounds per minute of manganese fed}$$

$$\frac{b \times 8.34}{10^6} = \text{pounds of manganese per gallon in sewer sample}$$

$$\frac{\frac{p \times m}{t} \times \frac{8.34}{10^6}}{\frac{b \times 8.34}{10^6}} = \frac{(p \times m)}{(t \times b)} = Q \text{ (gallons per minute)}$$

DISCUSSION

Dilutions methods for flow measurements have as a common advantage applicability to almost any physical condition. They are not limited as wiers are to sewers constructed so that wiers may be installed at the points where flow data is desired, nor are dilution methods effected by surcharging or by a high solids content. The other physical methods of measurement are similarly eliminated when suspended or floating solids clog or damage the metering equipment or when there is insufficient accessibility. The major disadvantage of dilution methods is the time consumed in the laboratory determining the degree of dilution. Complications such as color, the presence of an interfering ion, or a background variance of the trace element, introduce an additional step or steps in the analytical procedure or may affect the accuracy of the result. The classic chloride dilution method becomes necessarily complicated when the chloride level in the sewer requires massive additions of salt or when the color or other interferences considerably lengthens the chloride determination.

Since the physical conditions of the sewer system and the makeup of the waste are not readily subject to modification, the problem resolves itself into

one of finding a trace element for which there is a rapid, simple quantitative determination. Earlier experiments with colorimetric methods showed manganese to be a good trace element in the waste being measured. It had the advantage that it was not present in the waste in concentrations which would affect its use as a trace element and in addition there was readily available a supply of a technical grade of manganous sulphate. This form of manganous sulphate was packaged for easy handling, readily soluble, and comparatively inexpensive.

The colorimetric method for determining manganese was discarded as too time-consuming in this study because of chloride interferences. Flame spectrophotometric analysis was being used extensively and quite successfully in our quality control laboratory. The advantages which would be gained by applying this method of analysis to the problem prompted an investigation into the feasibility of its application. As a first attempt the equipment was used to analyze for the sodium ion in the salt dilution method. The use of the equipment proved practical but the sodium concentration in the waste was so variable that it eliminated sodium as a trace element. The advantage of manganese as a trace element which had been demonstrated by its use in the colorimetric method prompted an investigation of the possibilities of using it with flame photometry. The literature indicated that it was detectable at the 0.1 ppm level, but experimentation showed that for practical purposes 50 ppm was the minimum detectable concentration. Field experiments established that concentrations at this level could be economically attained.

This method combined the advantages of manganese as a trace element with a flame photometer's accuracy, simplicity, and relative freedom from complication due to interferences. It has as an additional advantage that where manganese and sodium may not be suitable for a trace element, it can be modified to fit any element detectable by flame photometry.

The results obtained checked quite closely with pumping records, the calculated amount of waste from the various processes; and the reproducibility of duplicate samples was good. Since the amount of waste from manufacturing processes such as was measured was never constant, absolute reproducibility could not be expected. Disregarding these fluctuations in twelve duplicate runs the variation in eight was less than 4.2%, the remaining four varied from 5 to 18%, with an average variation for the runs of 6.4%.

CONCLUSIONS

The use of manganese as a trace element and its detection by flame spectrophotometric analysis provides an accurate and relatively simple method of determining flows in sewers containing industrial wastes.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

MUNICIPAL ORDINANCES FOR INDUSTRIAL WASTES

Julian R. Fleming,[1] M. ASCE
(Proc. Paper 1085)

SUMMARY

In 1944 the City of Knoxville, Tennessee began engineering work on the design of a system of intercepting sewers, pumping stations, and sewage treatment plants that was completed in 1955 with the end of the construction period. This paper covers the main features of the ordinances and regulations set up by the City concerning reception of industrial wastes into the system and treatment plants. Principal features discussed are the system of charges and collections, features of the ordinance that protect the entire system and the employees from toxic and other types of harmful wastes, and a number of case histories of specific types of liquid wastes that have received special study. These include the soft drink industry, metal plating works, milk processing plants, meat packing plants, fertilizer plants, and paper manufacturing.

The Knoxville Ordinance

In undertaking to discuss this subject, the principal consideration will be given to the ordinances which have been adopted by the City of Knoxville, Tennessee, with a limited amount of attention to the more general aspects of the problem. The ordinances now in effect in Knoxville were passed by the City Council in 1954 and 1955.

Historically, this work began in 1944, when the City engaged the services of two firms of consulting sanitary engineers, Greeley & Hansen, of Chicago and Fredric R. Harris of Knoxville, to make a study of the needs of the City for a system of intercepting sewers and one or more sewage treatment plants, and to prepare an engineering report based on their findings. The report was submitted, and at a later date Greeley and Hansen was employed to design the interceptors and treatment plants.

Note: Discussion open until March 1, 1957. Paper 1085 is part of the copyrighted Journal of the Sanitary Engineering Division of the American Society of Civil Engineers, Vol. 82, No. SA 5, October, 1956.

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TABLE 1

Sewer Service Charges for Knoxville, Tennessee

Water Used, Cubic Feet per Month	Charge per 100 C.F. Inside City	Charge per 100 C.F. Outside City
First 500 (min.)	13 cents	20 cents
Next 3500	16	24
Next 6000	14	21
Next 10,000	11	16.5
Next 10,000	10	15
Next 10,000	9	13.5
Next 10,000	8	12
Next 20,000	7	10.5
Over 70,000	6	9

The above rates are net. After ten days past the due date of bill, add 10%.
Minimum bill inside city is 65 cents.
Minimum bill outside city is $1.00.

In 1953 bids were taken, and the work was begun, at a bid cost of approximately $6 million, to be financed entirely by revenue bonds. The bonds are to be retired over a period of about 35 years, with interest, operating expenses, and other costs to be met by a sewer service charge for all customers within the city if connected to the sewer system. The basis of the service charge is that each customer pays a percentage of his water bill for the sewer service charge. Table 1 shows the schedule for all classes of customers.

Billing and collecting is handled by the Knoxville Utilities Board, a municipally owned organization which distributes electricity, gas, and water.

Another type of billing structure is available to large water users, of which a single bracket is shown below for illustration. In this rate, a one year contract is agreed upon between the City and the customer. If the contract agreement is for a use range between 0 and 1,000,000 cubic feet per month, the customer pays a flat rate of $175 per month plus 4 cents per 100 cubic feet for all water used (that is returned to the sanitary sewer system), up to 1,000,000 cubic feet. If usage is beyond the contract figure, the customer pays 5 cents per 100 cubic feet for all over 1,000,000. Other brackets range up to 6,000,000 cubic feet per month in steps of 1,000,000. In this rate structure the bill is increased 50 per cent for service outside the City Limits, and the 10% penalty is applied for overdue bills.

It is the opinion of the author that an ordinance applying to the reception and handling of liquid wastes within a sanitary sewer system should consider the following principal factors:

1) Protection of the sewer system from substances harmful to the pipes, jointing material, and manholes, and protection of the workmen from gases or chemical poisons that may be discharged into the sewer. This includes exclusion of flammable or explosive substances of all kinds.

2) Protection of the sewage treatment plant from substances that may seriously interfere with its normal operation, such as overloading by slugs of concentrated material, chemical poisons, liquid wastes extremely high in B.O.D., suspended matter, color, or chlorine demand.

3) Setting up a fair system of charges for industry, so that each firm pays its proper share of the cost of handling and treating the waste.

Before going into more specific provisions of the ordinance and experiences with its use, a brief discussion is in order of the position of industry with respect to utilization of the city sewer system and treatment plant. Most, but not all, of the industries within the City of Knoxville now discharge their liquid wastes into the City sanitary sewer system, including wash room, toilet, drinking fountain, and miscellaneous sanitary wastes, in addition to the liquid wastes from manufacturing processes. Provided that pre-treatment of the wastes is done, producing an effluent acceptable to the City or to the State Health Department, (depending on which has jurisdiction in the particular case), the industry has the option of placing all of its liquid wastes into the City system, or of treating them before final disposal into a water course. In almost all cases that have arisen in Knoxville to this time, the industry has elected to discharge all polluted matter into the City system rather than to set up treatment facilities of its own. This is the more economical policy in most cases, especially where the industry is located in a medium sized or large city.

Two other possible conditions may also arise. One of these is that the industry may be asked to do a limited amount of pre-treatment or recovery, or both, prior to the acceptance of its liquid wastes into the City system. In this case also it will usually be to the economic advantage of the industry to use the city system.

The last case is that in which a part or all of the particular industrial waste will not be accepted by the City in its raw state, or in any state of pretreatment which the industry can reasonably supply. In such circumstances it may be necessary for the industry to give complete treatment to all of its wastes, to make substantial changes in the operating or recovery features of its processes, or in extreme cases, to move the plant to a more favorable location.

Some of the major items covered in the Knoxville Ordinance designated as "Rules and Regulations" are as follows:

1) All customers shall have approved meters on all water supplies which are ultimately discharged into the sanitary sewer system, or else shall meter the liquid wastes. For home owners this means that in almost all cases the customer pays the sewer service charge on all water used through his meter, but in the cases of commercial and industrial users who may use large amounts of unpolluted cooling water, and in the case of some industries who evaporate a portion of their water or return some of it unpolluted to the storm sewer, or use it in their product, one or more secondary meters may be used so that the customer can receive credit for that portion of water used but not returned to the sanitary sewer.

2) A rate beyond that given in Table 1 may be charged to industrial users if the biochemical oxygen demand, suspended solids, chlorine demand, or other properties of the waste are such that abnormal expense is incurred in the treatment plant in handling the waste. These properties are based on

periodic laboratory examination of the particular waste. At present such a penalty is not being applied, all customers being billed at a uniform rate per unit volume of waste contributed according to the standard billing policy. If in future the City decides that a surcharge should be imposed on certain customers, each case will be considered separately, and the billing policy recommended by the Consulting Engineers (Greeley & Hansen) will be passed upon by the City Council. In the opinion of the author, a surcharge should have been imposed on all industries from the beginning of operation of the treatment plant, based on B.O.D., suspended solids, and chlorine demand, if any of these characteristics exceed an established allowable limit for normal waste.

3) Within 18 months after the passage of the industrial waste ordinance, all industrial customers shall file certain information with the City. Within 21 months each shall express intention of accepting admission to the City system where pre-treatment is required or a surcharge is to be levied by the City. Within 24 months all who are to pre-treat shall submit plans to the City showing the proposed treatment facilities. Within 27 months the industry must show evidence that a contract has been awarded for construction where pre-treatment is necessary. All of the above time periods are from date of passage of the ordinance, and in special cases, a time extension may be granted.

4) Certain substances that may be present in industrial wastes are excluded from the sewer system either in whole or in part. In some cases a limited amount is permissible, and this may be based either on the individual plant or on the concentration of this material at the treatment plant from the entire system. Some typical examples are:

Liquids with temperature above 150 degrees F. excluded.

Grease or oil or other substance that will solidify or become viscous in the sewer excluded.

Gasoline or similar liquid or gas that is flammable or explosive excluded.

Substances which tend to settle out in the sewers and cause stoppage or obstruction to flow excluded.

Liquids which are corrosive or highly acid or highly alkaline excluded. pH must be between 5.5 and 9.5.

Toxic or poisonous substances excluded.

Iron, chromium, copper, and zinc limited at the treatment plant to 15, 5, 3, and 2 parts per million respectively.

Cyanides excluded.

Toxic radioisotopes excluded.

Highly colored wastes shall be excluded or subjected to special review.

Slugs of liquid wastes that may cause temporary overloads on the sewers or the treatment plant excluded unless discharged in a more uniform manner.

Specific provisions are included for certain types of industries, such as packing houses, poultry killing plants, milk products plants, plants producing oil wastes, and special regulations for plants whose wastes require pre-treatment or recovery before admission to the sewer system.

Some of the above provisions may seem to be rather hard on industry, but as long as the City and the industry approach the problem on a cooperative basis, with the honest intention of finding the best possible answer with the least hardship on the industry, and with acceptance of all wastes that can reasonably be handled at the treatment plant, the ordinance is reasonable and is

essential to the protection of the collection system and the treatment works. There may be occasional cases in which the City will find it necessary to use the ordinance to the fullest possible extent, but in general it will be done so that the most liberal possible use of the treatment facilities is available to industry.

During 1954 and 1955 the author was employed by the City of Knoxville as a special consultant on industrial wastes and on various other types of work in connection with the interceptor sewer system and treatment plants. While engaged in this work, he collected samples from various industrial plants, did laboratory examinations of those samples, and from the data obtained prepared reports and recommendations to the City concerning acceptance of wastes into the system with or without pre-treatment. It was also necessary to consider not only the effect of a particular industry on the sewer system and treatment plant, but to consider the collective effect of all industrial plants of a given type on the operation of the treatment plant, such as the milk products group, the meat packing group, metal plating, and others. A considerable amount of time and effort was used in determining what wastes or portions of wastes might properly go into the storm sewer, and what must go into the sanitary sewer. This work program was undertaken in advance of the completion of the main sewage treatment plant, since the plant was not put into operation until the Fall of 1955.

Knoxville has a sizable soft drink bottling industry, led by the Coca Cola plant, but including several others. Most of these plants were found to be discharging their process wastes into storm sewers, or directly into surface streams. Analysis of the wastes indicated that considerable pollutional matter was present in the typical waste from a soft drink plant. For example, a series of samples from one composite plant waste (excluding sanitary sewage) showed average pH of 10.0, total solids of 1200 ppm., dissolved solids of 1150 ppm., and 5 day B.O.D. of 570 ppm. It was obvious that this waste should not be discharged to the storm sewer or to a surface stream. Further investigation revealed that nearly all of the organic pollution resulted from the small amount of drink residue in the returned bottles. Elimination of the first portion of the bottle rinse generally permitted the remainder of the plant wastes, exclusive of sanitary sewage, to be discharged into the storm sewer, and therefore permitted the plant to receive credit on this portion of the water used.

Because of the toxic nature of their liquid wastes, metal plating works are always potentially dangerous to sewage treatment plants. Four plants doing this work were found in the City of Knoxville. One of these was a small specialty shop, another rather small, but handling on a semi-assembly line basis a considerable amount of chromium and other plating, another doing mostly plating of outdoor electrical fixtures with cadmium, and the fourth a very large plant in which many types of metal processing were done, including several plating operations. One plant was discharging its wastes into a closed storm sewer which later opened into a ditch, another into one of the creeks of the city some distance upstream from the river, and the large plant into a major creek a short distance from its mouth. The logical solution for this group of industries seems to be to take all of the wastes from the small plants into the city system, and to make a thorough investigation in the case of the large plant to see if the concentration of all important toxic materials can be kept within allowable limits at the treatment plant. If this cannot be done without pre-treatment, this will be required prior to the reception of this waste into the collection system.

The City contains a number of milk processing plants, but only three were considered to be of special importance to the operation of the sewage treatment plant. All three manufacture cottage cheese, and at the end of each batch process, all of the whey and several rinses is released in a short time into the sewer system. A detailed study of the largest of these plants was made, including sampling over a period of several weeks. Operating practices at the plant were found to be excellent, and in general the wastes contained very small amounts of milk and milk products, but the slug dumping of the cottage cheese whey vat imposed an extremely heavy B.O.D. load for a short time. Various tests of the B.O.D. of the whey showed values ranging from 26,000 ppm. to 48,000 ppm., average about 36,000 ppm. (all based on 5 day B.O.D.). The whey increased the B.O.D. population equivalent of the plant from 660 without the whey to 2800 with the whey included, and with the whey load concentrated into less than 30 minutes, the slug effect for the short time period was that of a population equivalent of about 100,000. The effect of this on the treatment plant could be disastrous. The recommendation to these three plants was that they remove the whey from the city sewer system completely, although the use of a 24 hour holding tank to release the whey gradually into the system would have improved the situation very much.

Knoxville has two medium size slaughter houses combined with meat packing plants. One of these has been connected into the city sewer system for years; the other is located near the Tennessee River and has used a private sewer to the river in the past. In the construction of the interceptor system, provision was made to take this plant into the city system. In both cases, the packing houses were asked to remove blood, hair, and all similar material, and to install a dual unit vibrating screen to remove most of the suspended matter from the paunch manure. They also were required to install an adequate and properly operated grease trap to exclude greasy and oily substances from the system. Except as noted above, all of their liquid wastes are accepted on the same basis as other wastes.

A fertilizer plant now located some distance from the city sewer system asked permission to build a private sewer to reach the city system, but this was refused on the basis of the very low pH of the waste and its high total acidity. Laboratory tests have shown a total acidity of 35,000 ppm., and a pH of about 1.0. The theoretical amount of water required to raise this pH to 6.0 would be 100,000 parts of water of pH 7.0 to 1 part of the waste.

One of the most difficult problems yet encountered in Knoxville is that of a company which manufactures brown paper for use in making cardboard boxes. The plant uses the neutral sulphite process. In addition to about 1,250,000 gallons per day of general wastes, the plant produces each 24 hours about 50,000 gallons of waste cooking liquor. The author's analysis of the cooking liquor showed a 5 day B.O.D. of about 19,000 ppm., and total solids of 220,000 ppm. A four hour composite sample taken during normal plant operation showed that the B.O.D. of the overall waste was about 930 ppm., and total solids of 9600 ppm. The overall waste has a very dark brown color, a medicinal odor, and responds very poorly to primary sewage treatment. Mixed with about 20 mgd. of city sewage, this waste gives a very distinct brown color to the entire mixture, and the same color goes through the sewage treatment plant and into the Tennessee River. At low flows in the river, a very noticeable color is present along the North bank of the river for hundreds of yards below the outfall. In addition to this, the waste has a certain amount of toxic effect on the normal bacteria in the sewage, and may have

harmful effects on the operation of the digesters at the treatment plant. At present the waste is being taken through the plant on a trial basis, but insofar as removal of color and solids is concerned, the results have proven little except that the plant cannot handle this type of waste. It is probable that the removal of the waste cooking liquor combined with more careful operation of the papermill will produce a waste that the city plant can handle successfully, and without the present very serious color problem.

Many other types of problems were investigated prior to the completion of the main sewage treatment plant, and some others have arisen since the plant started operation in 1955. An attempt was made to use foresight rather than hindsight in the solution of those problems specifically relating to industrial waste. No two city systems are the same, and in all probability each city will have to work out its own solutions as it passes through the various phases of building interceptors and treatment plants. The cases given above are typical of those that Knoxville has encountered, and include the ones that to this time have received the most serious consideration. Knoxville contains a number of textile mills, but except for some minor color problems, no serious trouble is expected from those because of the large dilution available from the remainder of the city wastes.

CONCLUSIONS

Knoxville's experiences with industrial wastes in the city sewer system and treatment plant show that an adequate ordinance regulating such wastes is essential to the proper operation of the system. Such model ordinances as that published by the Federation of Sewage and Industrial Wastes can be used as a general guide in the adoption of a local ordinance, but special local conditions must be taken into account, and for small cities, a short and simple ordinance will usually be preferable to a voluminous one. In all cases where industrial wastes present a major problem in the sewerage system, an engineering consultant should be employed by the city to sample the individual wastes, make analyses, and prepare reports on the proper handling of each type of waste. The experiences of one city will serve only as a general guide in the handling of this problem by any other city.

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SANITARY ENGINEERING DIVISION

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SED RESEARCH REPORT NO. 9

ON EVALUATION OF WATER RESOURCES OF A RIVER BASIN

BY The Sanitary Engineering Research Committee, Water Section

From Research Data and Report of: H. B. Wyndham, Jr.,* Instructor, North Carolina State College, Raleigh, N. C.

Acknowledgment: The Sanitary Engineering Division gratefully acknowledges the courtesy of the researcher and Mr. Charles Smallwood, Jr., Associate Professor of Civil Engineering at N. C. State College, under whose direction the research was performed, in making the report of this research available to the Society for review, presentation, and comment by the Water Section of the Research Committee.

Synopsis: A rational method of evaluating the water resources of a river basin is developed and applied to the Neuse River Basin in North Carolina.

Introduction:

The purpose of this study was to determine future trends of water use in the Neuse River Basin, North Carolina, and the relationship between these trends and the available water resources.

The major water uses in the basin are municipal, agricultural, and industrial. Municipal use can be charged to domestic residences, industries, commercial establishments, community agencies, and to leakage and waste. Agricultural use of water is composed of irrigation water and domestic water, including water used for farmhouse domestic purposes and that used in

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livestock watering and general cleaning. Industrial water use is defined by the author as that used by industry from sources other than municipal supplies.

The total supply of water is limited ultimately by the total rainfall reaching the basin, less consumptive use, according to the author. He defines consumptive use as the quantity of water transpired by plants during their growth or retained in the plant tissue, plus the quantity evaporated from the surfaces of soil, inland water, and vegetation. More simply expressed, consumptive use is that portion of the rainfall returned to the atmosphere from the basin itself.

Water resources become a concern when the demand approaches the supply.

Method of Analysis

A formula has been developed by the author to define the relationship between the water supply and demand for a river basin. The formula is:

$$R_f - C_u = (M_u + A + I + M_i)\frac{1}{n} = R_o$$

where R_f = Rainfall
C_u = consumptive use
M_u = municipal use
A = agricultural use
I = industrial use
M_i = miscellaneous uses
n = re-use factor
R_o = run-off

The factor "n" is introduced to account for the fact that rainfall which is not consumptively used can be used repeatedly. For example, a downstream city can use water which has been discharged as waste water from another city located upstream.

If total use at and above a given location equals runoff at that location, "n" will equal unity, i.e., the water is used only once, on the average. When use exceeds the supply, "n" is greater than unity, and vice versa.

Rainfall—and runoff—varies from time to time and from point to point in a river basin. Consequently, the equation should be applied only to a given time and location. The reuse factor, "n," will vary from year to year and season to season. Comparison of supply and demand and calculation of "n" would logically be based on critical low flows.

During low-flow periods (droughts), the demand may increase and is more likely to exceed supply than during wet periods. For example, agricultural use during a drought will increase where irrigation is practiced. A further ramification of the problem is that low flows provide less dilution of "used" waters (sewage) and lessen their value for reuse.

It is possible to store excess water in wet periods to increase water supplies during droughts. This will result in a lower "n," which is calculated from the following:

$$n = \frac{\text{Uses}}{\text{Runoff}}$$

It can be seen also that with a fixed supply, "n" will increase with the demand.

Information on the water supply and demand—and "n"—is of value to municipal planners preparing for the growth of their cities, to consulting engineers designing costly water and sewage works, to State agencies promoting new industries, to agriculturalists seeking irrigation supplies, and to State and Federal water resource agencies responsible for allocation of scarce water resources among various competitive users.

Predictions of future relationship between water supply and demand involves the study of rainfall and runoff records, present uses and trends, population and industrial growth, and availability of storage reservoir sites.

The results obtained in analyzing the uses and resources of water in the Neuse River Basin for 1950 and the year 2000 are as follows:

Type of Use	Quantity, m.g.d. 1950	Quantity, m.g.d. 2000
Municipal	29	130
Industrial	206	721
Irrigation	negligible	436
Rural	12	31
Miscellaneous	negligible	negligible
Total Uses	247	1,319
Resources (average year)	3,313	3,313
Reuse factor ($n = \frac{\text{uses}}{\text{Resources}}$)	0.075	0.398

The above data are for the entire river basin consisting of 5,098 square miles and for average water use and supply (resources). For a smaller drainage area of 1140 square miles and a 95 per cent dry year, the data are as follows:

Type of Use	Year 2000, Quantity, m.g.d.
Municipal	83.9
Industrial	360.0
Irrigation	197.8
Rural	7.2
Total	648.9
Resources (95% dry year)	84.4

$n = 648.9/84.4 = 7.69$

The author points out that irrigation will probably increase in the Neuse River Basin. Since irrigation water is largely consumed, i.e., lost by

evapotranspiration, the water resources available for the other uses will be decreased. This will increase the reuse factor, "n."

The author concludes that in part of the Neuse River Basin the available water resources will not meet demands in dry seasons without storage or without considerable reuse of water.

Discussion

This approach to the problem of comparing water supply and demand is an interesting and timely one. The supply-demand formula involving the reuse factor, "n," is a simple but effective way to express the relationship. Some such formulation is most useful in water-resource planning. The need for long-range planning is now generally recognized at all levels of government and industry.

This investigation of the Neuse River Basin emphasizes the growing practice of supplemental irrigation. Several authorities have called attention to the conflict between this use of water and other beneficial uses. Uncontrolled and unlimited use, or more correctly, consumption, of our valuable water resources for irrigation could have serious consequences. It is believed that some restrictions will eventually be necessary to prevent damages to other uses resulting from withdrawal and consumption of water for irrigation purposes.

The following comments are offered in the hope of improving the usefulness of this research to others.

1) Definitions

The term "consumptive," as applied to water use, has been defined by several authorities in various fields of interest. The definitions differ and it is difficult or impossible to apply any one of them to all activities of agriculture and industry. The author of this research has applied "consumptive use" only to evapotranspiration which would include most of the water used for irrigation purposes. It is important to remember that some industrial uses of water are "consumptive." Examples are evaporation and windage losses from cooling ponds or towers, makeup water replacing steam losses, and water becoming a part of the product. Some water is "consumed" in municipal uses also. Although most of the supplies withdrawn from surface streams is returned as waste water, a small part is lost for further use. It has been estimated that not more than 10 per cent fails to return to the water courses below cities.[1]

A committee of the American Water Works Association has suggested a generalized definition to cover both agriculture and industry, as follows:

Consumptive Use: Water, used in connection with vegetative growth, food processing, or incidental to an industrial process, which is discharged to the atmosphere or incorporated in the products of the process.[2]

This reviewer believes that this definition is more useful than the one presented by the author. Although it complicates the use of the supply-demand

1. "Water," 1955 Yearbook, U. S. Department of Agriculture.
2. Water Conservation in Industry, Report of Task Group A4, D1, American Water Works Association, Jour. AWWA, 45, 1249 (Dec. 1953)

formula, the AWWA definition would be more accurate. Estimates could be made of all consumptive uses and totaled under the term of the formula representing consumptive use, C_u. The terms, M_u, A, I, and M_i could be specified as the nonconsumptive portions of these various uses.

2) Nonwithdrawal Uses

The author has grouped several water uses under "miscellaneous," including recreation, navigation, and hydropower. He has pointed out that these uses are largely nonpolluting and nonconsumptive. It should be emphasized, however, that these uses can have definite effects on the quantity and quality of water available for other uses. For example, industry may be prohibited from using a stream as a source for cooling water where a rise in temperature would be detrimental to aquatic life and therefore to sport fishing. Water stored during wet periods for navigation or power releases increases the water available for other uses during critical low-flow periods. This has the effect of increasing the denominator of the relation.

$$n = \frac{\text{uses}}{\text{resources}}$$

and therefore reduces the value of the reuse factor, "n."

CREDIT

This research report, which is one of a series of professional contributions by the Committee on Sanitary Engineering Research,

William T. Ingram	Air Pollution
Nelson L. Nemerow, Chairman	Industrial wastes
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NEW DEVELOPMENTS IN SEPTIC TANK SYSTEMS

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(Proc. Paper 1088)

SYNOPSIS

During the past few years there have been some important changes in the design criteria for septic tanks and subsurface sewage disposal systems. These changes are set forth and evaluated.

INTRODUCTION

Important changes in design criteria for septic tanks and subsurface sewage disposal systems are now in the making. These changes are the result of recent field research, including studies and evaluations of available field data, and actual observations of field installations during construction, during normal operation, and after failures.

Public health workers in general, and sanitary engineers in particular, have become fairly familiar with the extensive studies which were started in 1946 by the U. S. Public Health Service on household sewage disposal systems. These studies resulted in three comprehensive progress reports[2,3,4] of which the last was published in 1954 under the auspices of the Robert A. Taft Sanitary Engineering Center in Cincinnati. Few may realize, however, the precautions being taken by the Public Health Service in a real attempt to correlate the results of the Cincinnati studies with practical observations in the field, and to limit recommendations based on the studies to practices

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2. "Studies on Household Sewage Disposal Systems," Part I, by S. R. Weibel, C. P. Straub, and J. R. Thoman, Government Printing Office, Washington, D. C., 1949.
3. "Studies on Household Sewage Disposal Systems," Part II, by T. W. Bendixen, M. Berk, J. P. Sheehy, and S. R. Weibel, Government Printing Office, Washington, D. C., 1950.
4. "Studies on Household Sewage Disposal Systems," Part III, by S. R. Weibel, T. W. Bendixen, and J. B. Coulter, Government Printing Office, Washington, D. C., 1954.

which may reasonably be expected under field conditions. To this end, and to assist in the preparation of a new manual of practice which may have universal acceptance, the Service has employed special consultants who have had extensive experience in the design, construction, operation, and repair of various types of septic tank systems. With the addition of this resource to the very considerable amount of talent already within the Service, it is believed that the forthcoming manual should be of particular value in reducing the number of failures of individual disposal systems.

The purpose of this paper is to summarize the more important changes which are expected in the new manual to be published by the Public Health Service. There is no assurance that all of them will be included because the final manuscript has not as yet been approved. Therefore, this report should be considered to represent the views of the writer only.

Septic Tank Capacity

Capacity is one of the most important considerations in septic tank design. Contrary to popular belief, sewage solids which have been subjected to anaerobic treatment in a septic tank cause much less clogging than the same amount of solids in the effluent from a primary settling tank where the detention time is short. Solids which are of a gelatinous nature in fresh sewage become more crystalline in sewage which has been subjected to anaerobic treatment during prolonged storage in a septic tank.

Large tanks providing for liberal sludge and scum storage capacities obviously have the additional advantage of permitting longer intervals between cleanings. In some cases, a 50 per cent increase in capacity will double the interval between cleanings, hence liberal tank capacity is not only important from a functional standpoint but is also good economy. When it is further considered that septic tanks were designed for the treatment of domestic sewage before the advent of household washing machines, synthetic detergents, and garbage grinders, and that many failures in existing systems have been attributed to increased loads resulting from the expanding use of such appliances, it becomes apparent that an upward revision of tank capacities is needed at this time. The capacities recommended are given in Table 1.

TABLE 1. LIQUID CAPACITY OF TANK (GALLONS)

Number of bedrooms	Recommended tank capacity	Equivalent capacity per bedroom
2 or less	750	375
3	900	300
4	1,000	250
For each additional bedroom add 250 gallons		250

Since less clogging is caused by an effluent from a tank in which prolonged storage has been provided, it is no longer considered justified to drastically reduce the detention time in large tanks such as those serving institutions, recreational areas and business establishments.

Compartmentation

It has now been well established that the performance of a two-compartment septic tank is superior to that of a single compartment tank in the removal of suspended solids and organic colloids. One of the reasons for this is the trapping action of the second compartment, serving as it does to allow settling of particles scoured out of the first compartment. The advantage of the extra removal in the second compartment is more significant than may be apparent at first glance. If, for example, 70 per cent of suspended solids is removed in a single compartment tank, and 80 per cent is removed in a two-compartment tank of the same total volume, then the suspended solids load on the leaching system is one-half greater from the single compartment tank. When it is considered that failures of leaching systems occur most frequently in tight soils, the superior performance of a two-compartment tank may mean the difference between success and failure in many instances.

Based on information presently available, the best design for home installations is believed to be a properly fitted two-compartment tank, with the volume of the first compartment equalling about two-thirds the total volume of the tank. It is not considered practical, however, to recommend definite requirements for two-compartment tanks in areas where single compartment tanks have given reasonable service.

Tank Proportions

Data now available indicate that relatively shallow tanks function as well as deep ones provided there is no sacrifice in capacity or surface area. Also, for tanks of a given capacity and depth, elongated tanks are as effective as those having length-to-width ratios of 3 to 1 or less. Thus, for large tanks especially, it should no longer be required that the length of a tank be no more than three times its width. Depths may range generally between 30 in. and 60 in.

Percolation Tests

The purpose of percolation tests is to obtain a quantitative measure of the hydraulic capacity of a soil to absorb clean water. The results are translated empirically into a measure of the ability of soil to absorb the effluent from a septic tank. The length of time required for percolation tests will vary in different types of soil. The safest method is to make the tests in holes which have been allowed to soak and to swell overnight. This is particularly desirable when the tests are being made by beginners, but is is not usually necessary if they are made by an experienced engineer. Tests should only be made in soil that is saturated, however, and several tests should be made in separate holes until the water seeps away at a constant rate,[5] or until equilibrium conditions are reached.[6,7] The need for continuing

5. "Subsurface Sewage Disposal," by John E. Kiker, Jr., Bulletin No. 23, Florida Engineering and Industrial Experiment Station, Gainesville, Florida, December 1948, p. 24.
6. "Improved Soil Percolation Test," by Harvey F. and Gordon W. Ludwig, Water and Sewage Works, Vol. 96, May 1949, pp. 192-194.
7. "Equilibrium Percolation Test," by H. F. Ludwig, W. D. Ward,

percolation tests for sewage absorption systems until such a degree of consistency is obtained in the results was pointed out first in 1948,[5] and again in 1949[6] and 1950.[7,8] It was later re-emphasized in Part III of the Cincinnati studies[4] which advocated overnight swelling for certain types of soils. Although it has been agreed that soaking and overnight swelling have some advantages, it has been found that in most cases the shorter or "single-visit" tests will give comparable results if they are performed properly; that is, if the instructions for them are followed and if the tests are continued until the results become consistent. Failure to do this has been the primary reason for such discrepancies as have been reported. Pending the development of further basic data, both types of tests are being recognized and are considered acceptable under conditions which will be explained in greater detail in the manual.

Leaching System Design

For the most part, the design of different types of leaching systems has been based upon original work by Henry Ryon who recommended, in effect, that the leaching surface area of seepage pits be equal to about 75 per cent of the area required in subsurface irrigation fields or absorption trenches.[9] In some sections of the country, however, it has been found that seepage pits which are so designed will fail much earlier than absorption trenches. As a result, some localities have required larger areas for seepage pits than for absorption trenches; which is just the opposite of Ryon's recommendation.

These experiences indicated a need for further investigation and for a reappraisal of the factors which were formerly thought to influence the functioning of subsurface disposal systems of all types. It was commonly believed that the permissible loading on seepage pits could be greater than that on seepage trenches because of the greater head of water in pits. In most places, it was also common practice to allow only for the sidewall area in seepage pits, and only for the bottom area of seepage trenches. In 1952, Ludwig[10] pointed out that this was inconsistent and he expressed the belief that all of the available contact area should be equally considered. It may be added that the inconsistency becomes glaringly apparent when combinations of the two types of systems are used in a single installation.

The reports of failures of seepage pit systems in places where seepage trenches functioned satisfactorily under conditions that were considered reasonably comparable (except for reductions in leaching area as described previously), led to doubt as to the importance of head and other hydraulic factors in the operation of leaching systems. Although such factors are significant in percolation tests with clean water, since the rate of percolation will depend

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W. T. O'Leary, and E. Pearl, Water and Sewage Works, Vol. 97, Dec. 1950, pp. 513-516.

8. "Rational Design Criteria for Sewage Absorption Fields," by John E. Kiker, Jr., Sewage and Industrial Wastes, Vol. 22, Sept. 1950, pp. 1147-1153.
9. "Notes on the Design of Sewage Disposal Works with Special Reference to Small Installations," by Henry Ryon, Albany, N. Y., 1928, p. 15.
10. "Equilibrium Percolation Test for Estimating Soil Leaching Capacity," by H. F. Ludwig and John Stewart, Modern Sanitation, Vol. 4, Oct. 1952, pp. 61-66.

upon the true hydraulic head which "includes the pull of the suspended water" below the test hole,[8] it appears that different phenomena predominate when sewage effluent is applied to a leaching area.

To start with, the amount of sewage applied is much smaller, relatively, than the amount of water used in a percolation test; the ratio being about one to forty. A controlling factor when sewage is applied to a leaching system is the surface area available for the decomposition of the suspended material and organic colloids which are filtered out in the leaching process, such decompostion being essential to prevent the surface from clogging prematurely. In other words, the hydraulic factors are relatively unimportant as compared to the available surface filtering area, and a given area should be considered about equally effective whether it is horizontal or vertical. This leads to the conclusion that the same design criteria should be used in computing the required area for seepage pits as for seepage trenches, and for combinations of the two. Considering the wide variations in dimensions of seepage pits, which may range from 4 ft. in diameter and 90 ft. deep in one part of the country, to upwards of 10 ft. in diameter and 4 ft. deep in another, there seems to be little justification in continuing to adhere to the initial concepts which were based on a limited amount of work in an area where the pit dimensions varied over a relatively narrow range. Indeed, the extremely deep pits of small diameter may impress one as being merely a vertical trench, and there is something to be said of the similarity.

For percolation rates not less than one inch in 30 minutes, the writer recommends that the same absorption areas be required for seepage pits as for trenches. Soils having rates slower than one inch in 30 minutes are considered unsuitable for seepage pits, but shallow trenches are considered acceptable if the rate is not slower than one inch in 60 minutes. This allows for some evapotranspiration where the disposal area is shallow.

The recommended absorption area requirements are summarized in Table 2.

Although not recommended for household installations, trenches deeper and wider than those generally permitted in the past are now recognized as having practical application in special cases or large systems. This is based on the premise that a deep trench is essentially a combination of a horizontal trench with the vertical pit, and it constitutes an acknowledgment of observed successful uses of wide trenches in some places. Due allowance is made for the extra depths and widths.

Further Research Needs

Some 1200 products, including some containing enzymes, have been placed on the market for use in septic tanks and extravagant claims have been made for some of them. So far as is known, however, none of them has been proved of advantage in properly controlled tests by an educational institution or by a reputable testing laboratory, although several universities have excellent facilities for fundamental studies which could be used to advantage on properly sponsored research projects. Laboratories operated on government funds derived from taxes are seldom permitted to make tests on proprietary products.

There is conflicting information concerning the effects of synthetic detergents on septic tank systems. Studies at the Robert A. Taft Sanitary

TABLE 2. ABSORPTION AREA REQUIREMENTS FOR PRIVATE RESIDENCES

Percolation rate (Time in minutes required for water to fall 1 inch.)	Required absorption area, (1) sq. ft. PER BEDROOM (2)
1 or less	70
2	85
3	100
4	115
5	125
10	165
15	190
30	250
45	300*
60	330*
Over 60	Unsuitable for any leaching system.

(1) Absorption area for standard, narrow and shallow trenches should be figured as the bottom trench area. For extra deep, wide trenches, allowance should also be made for the effective sidewall area below the first foot underneath the distributing pipe. For leaching pits, the absorption area should be figured as the outside area of walls in pervious strata beneath the inlet. In computing the outside area of leaching pits, use dug diameter and allow full credit for rock backfill outside the walls.

(2) In every case sufficient area should be provided for at least two bedrooms.

*Unsatisfactory for seepage pits.

Engineering Center showed that none of seven brands of household detergents interfered with normal sludge digestion when used in quantities representing average household use for all purposes, but several of the brands noticeably interfered if used in quantities representing more than average use. Other studies have indicated that detergents cause no more short-time clogging than is caused by soap, but it was found in the studies referred to above that one detergent did slightly more damage to soil structure.

Testimony by experienced engineers, sanitarians, septic tank installers, and others, has indicated that the new detergents have a marked effect in shortening the life of soil absorption systems. There remains a real need for research in which proper controls are used to compare the effects of proprietary products in parallel installations where the use and nonuse of synthetic detergents are the only variables. Here again, however, no manufacturer has yet seen fit to underwrite a research program in which

comprehensive comparisons can be made in installations where actual field conditions can be simulated for prolonged periods. Although it may be agreed that average amounts of detergents will have no adverse effects on septic tank systems, the fact remains that there are some six million septic tank installations within the country and if detergents caused annual failures of only one per cent of this number that would still account for 60,000 failures a year. Therein may lie a reason for the apparent discrepancy between published research results and field observations of those who continue to insist that the new detergents have been responsible for many failures.

There is a bright side, however. The septic tank capacities now recommended are reasonably liberal. They provide for a 50 per cent increase to allow for household appliances including garbage grinders. It is apparent that this should result in better conditioning of the effluent which is discharged to subsurface disposal systems and that this, in turn, should result in fewer failures.

The need for further research was pointed out on March 22, 1956 in a report to the Federal Housing Administration from the Building Research Advisory Board. Under a contract between the FHA and the National Research Council, the BRAB conducted a study of existing data to evaluate the various opinions, observations and research regarding the "Effect of Automatic Sequence Clothes Washing Machines on Individual Sewage Disposal Facilities." A special advisory committee was appointed for the study, and members of the committee "were selected on the basis of their knowledge and experience as individuals in the subject of the study."[11]

In addition to the observation that further research is needed, the major conclusion of the committee was to the effect that:

> "A properly designed individual septic tank and subsurface drainage system can be used effectively in disposing of all liquid household wastes including both sewage and the discharge of automatic sequence clothes washing machines in the same system." (Italics added).

The committee also agreed that it is unnecessary to have separate systems for the disposal of sanitary wastes and laundry wastes from an automatic washing machine; also that laundry wastes may be advantageously treated by the buffering action, the lint removal, and the biochemical action which occurs in the septic tank employed for the sanitary wastes. ". . . Except in rare cases, there will be an economic advantage in having a combined system for disposal of sanitary wastes and laundry wastes," according to the report.

However, the report does not recommend against separate systems for laundry wastes and it is believed that separate systems should be allowed where home owners wish to go to the extra expense of installing them. Although septic tank installations should not be allowed in new developments where a single disposal system will not be satisfactory, it appears that separate systems for laundry wastes are sometimes desirable in marginal areas or in areas which were developed before home water consumption was increased as a result of the use of automatic washing machines.* In such a

11. "The Effect of Automatic Sequence Clothes Washing Machines on Individual Sewage Disposal Systems," A Report to the Federal Housing Administration by the Division of Engineering and Industrial Research, Building Research Advisory Board, Washington, D. C., March 22, 1956.

* Of 159 replies from health departments, to a letter of inquiry from the BRAB, 89 indicated that individual sewage disposal systems will function

separate system, a replaceable rock filter may be found better than a septic tank for the removal of lints and fines from the wastes.

SUMMARY AND CONCLUSION

At best, septic tanks and subsurface sewage disposal systems are poor substitutes for central collection and treatment systems. Septic tanks were designed for the treatment of domestic sewage before the advent of household washing machines, synthetic detergents, and garbage grinders. Since they are likely to create public health problems which may be difficult to correct, septic tank disposal systems should be avoided wherever possible. In general, they should be used only in rural areas of large acreage, where suitable soil is available for disposal of the effluent by subsurface means. They should not be used in places where the soil is impervious, or where the maximum ground water table comes within four feet of the surface during the wettest season, or where the subsoil conditions are otherwise unsatisfactory. Nor should they be used in locations where there is any likelihood of contaminating a water supply, lake or other water course.

When septic tanks have to be used, they should be of adequate capacity to allow for increased loads from modern home appliances. The disposal systems following the tanks should also be liberally designed in accordance with sound engineering principles which include determinations of soil characteristics through subsurface explorations in addition to properly conducted percolation tests. There should be no compromise by allowing installations of inadequate septic tank systems as a means of competing with central sewerage and sewage treatment facilities. At the same time, antiquated traditions should be abolished and reasonable departures from standard practices should be allowed where they have proven successful.

These objectives may be accomplished by following the procedures recommended in the new "Manual of Septic Tank Practice" to be published by the U. S. Public Health Service.

ACKNOWLEDGMENTS

The Joint Committee on Rural Sanitation, sponsored by the U. S. Public Health Service under the chairmanship of Malcolm C. Hope, are performing an important role in reviewing and revising the manuscript for the manual on which this paper is based. Members of the Joint Committee made valuable suggestions for improvements to the manuscript. Most of the writer's initial work on the manual was done at the Robert A. Taft Sanitary Engineering Center in Cincinnati, in collaboration with James B. Coulter, Samuel R. Weibel, and others who were associated with the Cincinnati studies.

Reports prepared in 1952 and 1954 by the Rural Sanitation Committee of the American Public Health Association were used as major sources of information. Contributions of exceptional practical value were made by Harvey F. Ludwig and James J. Spear. As Milton has put it, to them is due the "debt immense of endless gratitude."

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satisfactorily with combined sanitary wastes and wastes from automatic sequence washing machines, <u>if properly sized for the increased liquid volume.</u> But 36 indicated that "separate sewage disposal facilities should be provided to dispose of waste from automatic sequence washing machines." (About 30 reported no information on the subject of the inquiry.)

Journal of the

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

PRELIMINARY STUDIES ON COMPLETE ANAEROBIC SEWAGE TREATMENT[a]

J. B. Coulter,[1] S. Soneda,[2] J.M. ASCE, and M. B. Ettinger[3]

(Proc. Paper 1089)

SYNOPSIS

Laboratory studies are described for the development of an anaerobic contact sewage treatment system for use in small subdivisions which produce an effluent low in B.O.D. and low in suspended solids.

INTRODUCTION

Approximately 400,000 septic tank systems will be constructed in the United States in the next year. Six million individual household sewage disposal systems are already in use, and many million more will be installed unless some other trend is developed. Millions of these systems work to the satisfaction of both the owner and the health official, but in spite of rigorous efforts on the part of health authorities absorption systems have been and are being installed in poor soil where there is no hope of successful operation. Even in good soil, poor construction and indifference or ignorance on the part of some home-owners will result in early failures. The possibility of mass failure of septic tank systems and the resulting contamination of the environment is a matter of concern to every authority acquainted with the problem.

Clearly there is need for a low cost, efficient sewage treatment plant tailored to the needs of small groups of houses, ranging from several to

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a. Presented at a meeting of the ASCE, Knoxville Convention, June 4-8, 1956, Knoxville, Tenn.

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3. San. Engr., Public Health Service, U. S. Dept. of Health, Education, and Welfare, Cincinnati, Ohio.

several hundred. This paper describes the first of a series of studies aimed at the development of such a plant in which the following features are essential:

Performance.—Effluent must be safe for discharge with very little dilution water, and the plant and effluent must be free of nuisance because both will be in close proximity to the houses served.

Operation and Maintenance must be simple, dependable, and foolproof. Someone must keep the plant running, and because revenue is limited to a few dollars per house per month, operation must be simple or it will be neglected.

Initial Cost per house should compete with the cost of a septic tank system, taking an allowance for increase in house value resulting from a central system. Furthermore, the smaller the initial cost the less resistance there will be to the organization of a unified sewer district when the area is fully populated.

The last two requirements call for a plant with a minimum of mechanical equipment, a design most likely to be achieved by eliminating the necessity to supply air or to maintain aerobic conditions. There is reason to believe,[1][2][3] that good, nuisance-free treatment can be obtained with the anaerobic process. Furthermore, it is believed that the anaerobic process can be used in a manner similar to its aerobic counterpart. To be specific, when a waste with soluble B.O.D.-producing material is brought into contact with an active anaerobic sludge, B.O.D. will be transferred from the liquid to the sludge. This transfer in conjunction with subsequent stabilization and disposal of the sludge constitutes sewage treatment.

Three unit processes are involved. The first is the transfer phenomenon, which can be accomplished by bringing the waste into contact with sufficient sludge for sufficient time. The second is the separation of sludge from the treated liquid effluent. The third is the stabilization and disposal of sludge. All three processes are important to sustained successful operation of a sewage treatment plant.

Experimental Apparatus

A laboratory model of an anaerobic plant was assembled as shown in Figure 1. Sewage was obtained from a residential sewer and constantly stirred in the feed bottle. The whole sewage was then pumped to the sludge contact chamber at a rate of 4.5 cc per minute or 6.5 liters per day. Feed entered the contact chamber near the bottom and flowed upward through the sludge to a siphon located at about the third-depth point. By means of the siphon, liquid was conveyed to the bottom and passed upward through a rock-filled column. Final effluent flowed through a trapped outlet and was collected in a jar large enough to hold the entire day's flow.

The sludge contact chamber had a capacity of 9 liters and was seeded with 1 liter of sludge taken from an active digester. The rock column was composed of a 3-inch base course of 3/4 to 1/2 inch gravel supporting 12-inches of 1/2 to 1/4 inch gravel and contained in a section of 3-inch glass pipe. The voids ratio was approximately 0.4 giving a liquid capacity of 700 ml. and a theoretical retention of 2.5 hours. A constant displacement pump of the

Brittingham type, the only mechanical equipment in the set-up, was used to lift sewage into the contact chamber and regulate the flow. Flow through the rest of the system was by gravity.

Procedure

A trial run was made at room temperature to test the workability of the scheme. A month was sufficient to demonstrate that the unit could be run with very little attention. In addition, a clear effluent practically free of odor was produced. Effluent B.O.D.'s ranged between 12 and 39 p.p.m. during the final week of the run as compared with an influent average of 200 p.p.m. A very effective removal of suspended solids was recorded throughout the run. The highest value observed was 17 p.p.m. and on several days there were no measurable suspended solids in the effluent. The sludge volume decreased slightly and some material accumulated in the rock column, but there was no measurable increase in head loss. At the end of the run, a plug at the bottom was removed and the column was allowed to drain. As it emptied the deposit also came out leaving the rock purged and clean.

After the workability of the laboratory unit was substantiated, a plan was devised to test it under severe temperature conditions. The unit was cleaned, dismantled and reassembled in a constant temperature room set at 4°C. A new supply of anaerobically stabilized sludge was used in the sludge contact chamber and new rock was used in the column. After 10 weeks at 4°C the temperature was raised in three increments of 7° each with three days for adjustment after each raise so that in a period of less than two weeks the temperature was raised from winter to summer values.

Waste was taken from a manhole in a residential district of Cincinnati. Although this source was free of industrial wastes, it was greatly influenced by rainfall and snow runoff. Sewage fed to the unit averaged 181 p.p.m. 5-day B.O.D., but waste as weak as 42 p.p.m. was used on one isolated occasion.

Results

The per cent removal of 5-day B.O.D. is shown on Figure 2. Plotted values are 5-day weekly averages. During the cold period removals ranged between 53 and 78 per cent with an average of 67 per cent. In the period of adjustment as the transition was made from cold to warm temperatures, effluent B.O.D. rose from an average of 55 to values in excess of 100 p.p.m. The period of disturbance lasted for one week. After adjustment, performance was much better than that observed during the cold run. Average removal for the final 14 weeks was 81 per cent, and only on two occasions did the weekly average fall below 80 per cent. Weekly averages for the effluent 5-day B.O.D. ranged between 12 and 56 and averaged 26 p.p.m. for the same period.

As shown on Figure 3, suspended solids removals were exceptionally high during both the cold and the warm runs. Only on three occasions did removals drop below 90 per cent, and that was during the period of temperature adjustment. The quality of the effluent is indicated by the suspended solid content also shown on Figure 3. The highest daily value was 42 p.p.m. observed during the first week, and for the final 5 weeks the daily value rose above 10 p.p.m. only on three occasions. A considerable quantity of solids, either

growth or sediment, was trapped in the rock, but there was never any indication of unloading or clogging.

Effluent pH was uniformly on the alkaline side, ranging from 7.4 to 8.0. Dissolved oxygen determinations were made periodically throughout the system and were found to be zero in every case. An attempt was made to trace the fate of sulfur by making both sulfate and sulfide determinations on influent and effluent. There was a loss in sulfate that could not be accounted for by a rise in sulfide content. The appearance of a white amorphous substance suggested that sulfur was being reduced to the free state. More elaborate analytical work will be required to establish this point.

Considering the long retention time involved it seemed advisable to compare the treatment achieved in the unit with that which could be obtained through sedimentation alone. For this purpose a portion of each day's feed was allowed to stand and a B.O.D. determination made at the end of 24 hours. In general the reduction in B.O.D. was between 50 and 60 per cent, substantially less than that obtained in the unit.

B.O D. removals were calculated on the basis of 5-day determinations. If in passing through the unit the character of the effluent was altered to give a substantial lag phase in the B.O.D. curve so that the 5-day value was low in spite of a potential high demand, dangerously misleading results would be obtained. To check this possibility two time-sequence studies were made on both the influent and effluent. These studies demonstrated that there was no lag in the effluent B.O.D. and that the 5-day values could be compared to give a satisfactory parameter for the efficiency of the unit.

From the standpoint of operation and aesthetics, the unit was successful. It required practically no attention other than the daily change of feed and the sampling operation. Although a deposit built up in the rock column there was no tendency to clog. The effluent, though slightly colored, was clear and surprisingly free of odor. Hydrogen sulfide could be detected on close examination or when the effluent jar was emptied. Figure 4, a photograph of the unit in operation, clearly shows the contrast between influent and effluent.

Discussion of Results

The laboratory trials of the anaerobic contact process are considered successful. The unit was operated with little attention for a period of 6 months, and nothing was observed which might indicate operational difficulties. No appreciable scum formed, nor were there signs of digester upset even under a severe test applied by a rapid change in operating temperature. In this scheme the sludge is constantly washed by incoming sewage so that there is no opportunity for accumulation of volatile acid and sour supernatant often associated with malfunctioning digesters. Clogging did not seem to be a factor even though material accumulated in the rock column.

Effluent was clear and relatively free of odor. A higher level B.O.D. reduction was obtained at warm temperature than at cold, but remaining B.O.D. was low in both cases. Effluent suspended solids were actually negligible throughout the entire trial. Although emphasis is on service for groups of houses, the low suspended solid content is good for soil absorption, and there is no reason to rule the system out of consideration for the individual home.

Total retention time, approximately 35 hours, resulted from the selection of convenient laboratory equipment and feed rates rather than preconceived

design factors. It is impractical to attempt to evaluate the influence of such factors as long thin tubes, greater surface areas per unit volumes, feed procedures, sampling, and other conditions peculiar to a small bench scale device. The main purpose of the laboratory trial was to establish the workability of the arrangement under various temperature conditions. With that established, the development of engineering design factors depends on large scale experiments under field conditions.

Future Development

With the consent and cooperation of the village officials at Loveland, Ohio, a pilot plant is being constructed at the Loveland sewage treatment plant. Loveland is essentially a residential community located near Cincinnati, served by a plant incorporating comminution, primary sedimentation, a trickling filter, and separate sludge digestion.

The pilot plant will take comminuted sewage from the primary influent and discharge back into the primary effluent. Feed will be by an adjustable pump making it possible to investigate the effect of retention time, recirculation, and organic loading. With the larger unit it will be possible to evaluate the treatment obtained in the contact chamber in relation to the rock column and to determine the optimum relationship between the two.

The sludge problem can also be appraised in a large plant. Ideally it might be necessary to withdraw sludge only once each year in a well stabilized condition. On the other hand it might be necessary to draw sludge at frequent intervals and convey it to a separate digester. This is the type of question which can be answered only by using large units and an adequate volume of sewage.

SUMMARY

1) A simple anaerobic contact system has been investigated in the laboratory. An inoffensive effluent low in B.O.D. and very low in suspended solids has been produced. Observations indicate that an inexpensive treatment plant with small maintenance requirements can be designed.

2) As a result of highly encouraging laboratory results, a pilot plant is being constructed. Actual development of the process, including loading rates and other engineering design criteria, will be obtained from trials with the pilot plant.

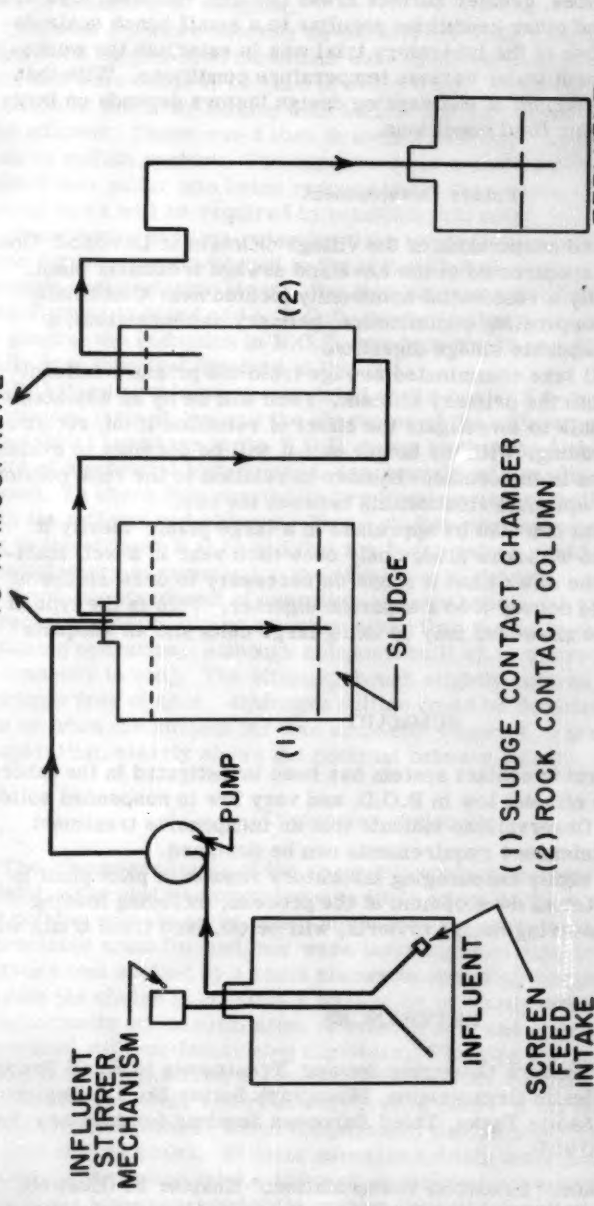
REFERENCES

1. Meinch, Dr. F., "Factors Governing Sewage Treatments in Small Sewage Plants." World Health Organization, Monograph Series No. 18, Design and Operation of Septic Tanks, Third European Seminar for Sanitary Engineers, Geneva (1953).

2. Underkofler, Leland, "Industrial Fermentations" Chapter 14 (Buswell, A. M.) pp. 518 to 555, Chemical Publishing Company, New York, New York (1954).

3. Fuller, W. J., "Anaerobic Digestion of Packing Plant Wastes." Sewage and Industrial Wastes, 25, 576 (May 1953).

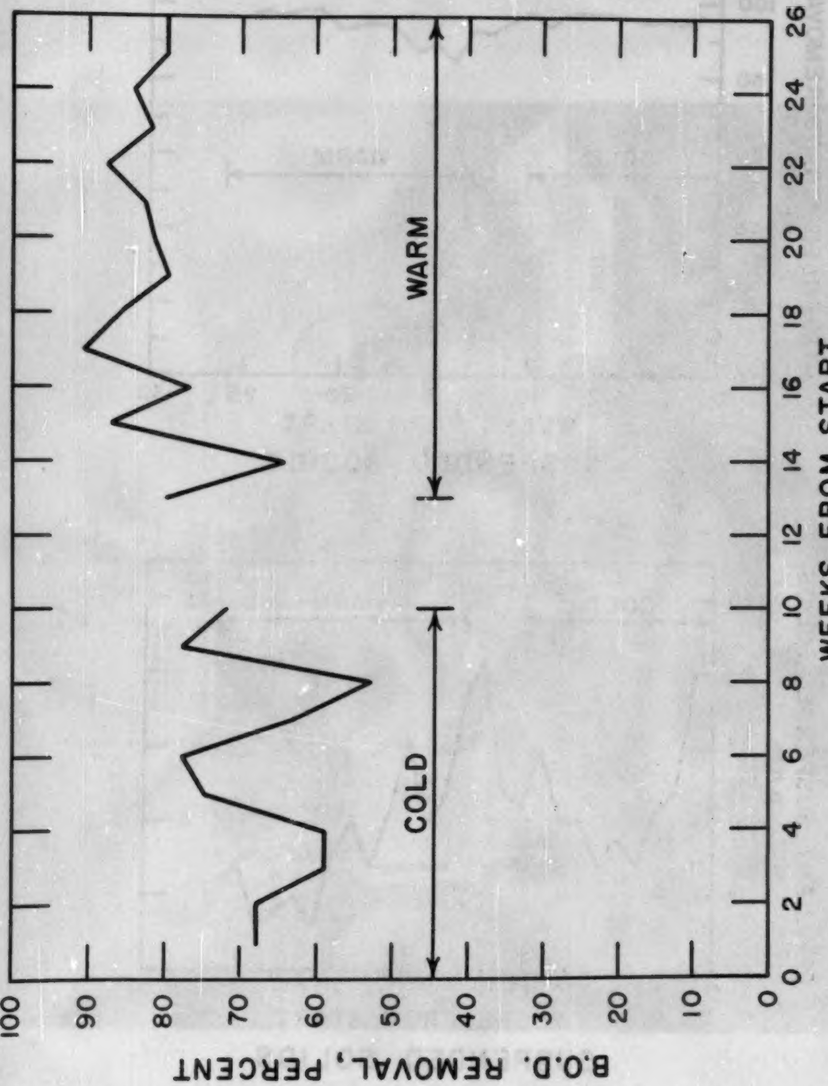
4. Rudolfs and Zeller, "Effect of Sulphate Salts on H_2S Production in Sludge Digestion," Sewage Works Journal, 4 (May 1932).



SCHEMATIC DRAWING

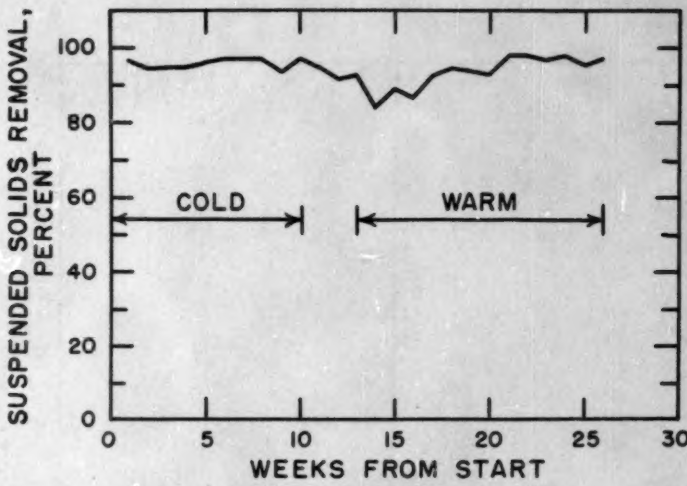
ANAEROBIC CONTACT TREATMENT UNIT FOR DOMESTIC SEWAGE

FIGURE 1

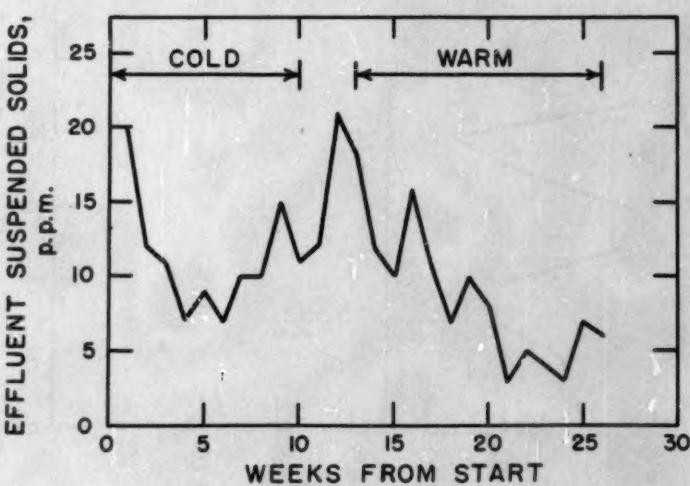


B.O.D. REMOVAL, PERCENT

FIGURE 2



SUSPENDED SOLIDS



SUSPENDED SOLIDS

FIGURE 3

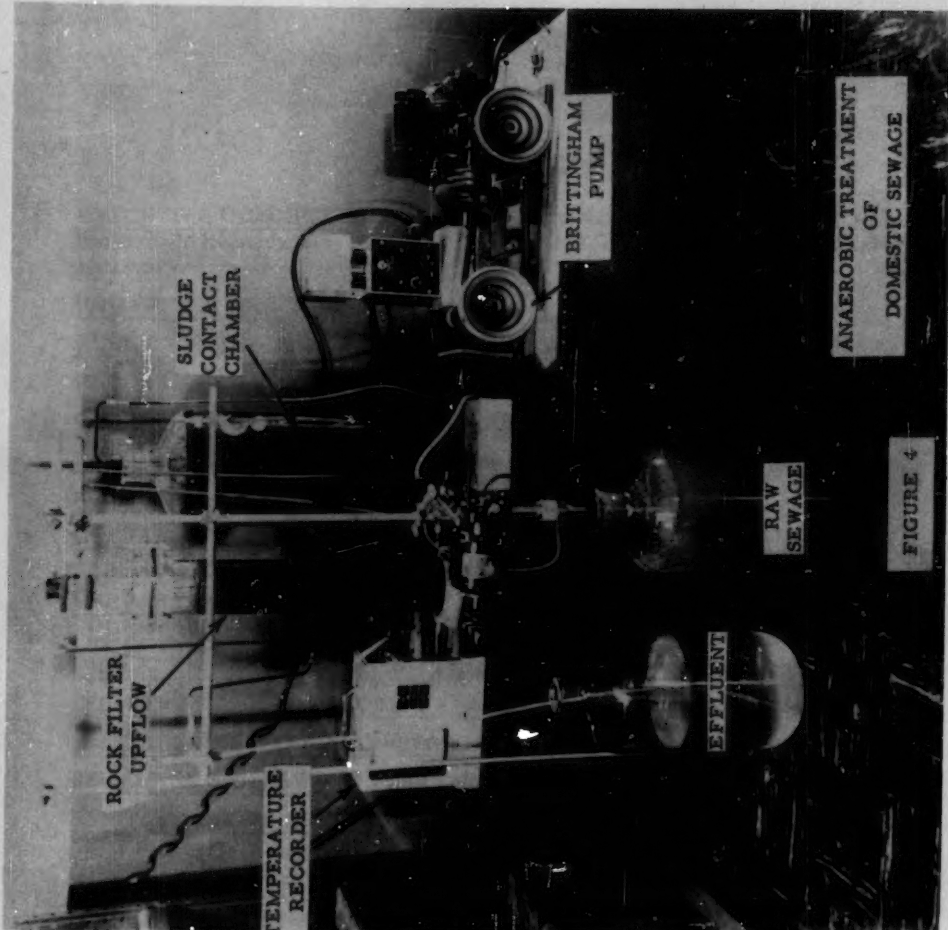

SLUDGE CONTACT CHAMBER
BRITTINGHAM PUMP
ANAEROBIC TREATMENT OF DOMESTIC SEWAGE
ROCK FILTER UPFLOW
TEMPERATURE RECORDER
EFFLUENT
RAW SEWAGE

FIGURE 4

SUSPENDED SOLIDS

FIGURE 3

DIVISION ACTIVITIES
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

NEWSLETTER

October, 1956

1955-56 DIRECTORY

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PROFESSIONAL DEVELOPMENT AND PUBLICATIONS

Ross E. McKinney

One of the most important aspects of professional development of an engineer is recognition of his professional competence by other engineers. Locally, the engineer gains recognition by personal contact at local technical meetings. Beyond the local level it is difficult for the average engineer to gain recognition. At the state and national level the individual finds it very difficult to gain recognition as most of the recognition goes to the firm for which he works.

Lack of recognition is one of the most frustrating factors facing the junior engineer. Not only is the junior engineer in the field of Sanitary Engineering considerably underpaid in relationship to the junior engineers in almost every other branch of engineering, but he also fails to receive proper recognition from his employer for a job well done. He does not receive the full satisfaction that he has done a very valuable piece of work nor that he has made a direct contribution to the success of the particular project on which he has worked. For the most part, the employer is a professional engineer who has already received recognition at a local level, a state level and usually at a national level. The employer likes to receive recognition for a job that his firm has handled ably but he is usually too busy to pass that recognition on to the junior engineer whose work made the project a success and without whom the project could not have succeeded.

For the most part recognition of one's engineering achievements comes through publication of the results of a particular project. The widespread distribution of the many technical journals in the Sanitary Engineering field can very quickly permit the junior engineer to receive the recognition that he deserves. Repeated publication of articles of a high technical caliber can have a very direct bearing on professional recognition and professional advancement of the junior engineer. This is very readily recognized by the employer. If his junior engineers receive the professional recognition to which many of them are entitled, the employer is faced with having to pay his junior engineers salaries to which they should be entitled or with losing them to firms who will pay them salaries more in line with their value. This is not desirable and so the junior engineer is very seldom permitted to write about the work he has done. Instead, the employer takes the data obtained by the junior engineer, writes it up and presents it for publication as his personal work without the slightest mention of any junior engineers who made the article possible.

Recognition is a little thing. It costs nothing but the returns are great. Most junior engineers know enough about finances to realize that the firm for which they work is paying them the maximum salary that it can afford. While everyone can use more money, salary is not the prime factor in holding or losing junior engineers as long as they are being paid a living wage. The two most important things to the junior engineer are the type of work that he does and the recognition that he receives for a job well done.

Every effort should be made by engineering firms to encourage their junior engineers to prepare technical papers on the work that they are doing. It will give the junior engineer the chance to demonstrate his ability and to receive national recognition as well as local recognition. It will give the junior engineer a sense of accomplishment and of pride in his work. It will also spread the firms' name at the same time.

The Journal of the Sanitary Engineering Division is primarily directed towards the professional engineer in the field of Sanitary Engineering. Its objective is to publish technical papers related to sanitary engineering projects. Many of the papers published in the Journal have been presented at the technical meetings of the ASCE but many of the papers are presented here for the first time. The Journal earnestly solicts manuscripts from all engineers interested in their own professional development and in professional recognition. It is hoped that more junior engineers will take advantage of the opportunities afforded by publication in the Journal.

RADIOACTIVITY AND WATER RESOURCES

The extensive publicity given the National Academy of Sciences'—National Research Council—recent report entitled "The Biological Effects of Atomic Radiation" has served to focus more and more attention on the effect of an expanding nuclear technology upon the quality of our vital water resources.

The sanitary engineer is intimately concerned with the actual and potential contamination of the environment with radioactive wastes. Many State sanitary engineers are presently faced with the problem of initiating programs for the control of the radioactive pollution of surface waters. A brief consideration of one such program—that of Indiana—might prove enlightening to other sanitary engineers, whether associated with State health departments, industry, or consulting firms.

The Division of Sanitary Engineering, Indiana State Board of Health has started a program to secure radiological background data for streams, particularly where surface water supplies are involved. At the present time eight sampling stations have been established where samples are collected monthly. As soon as additional laboratory equipment is procured, it is planned to collect samples from at least eight more stations. This will cover all of the major streams and the southern tip of Lake Michigan. The data will be used as a basis for detecting any increase in radioactivity as a result of radioactive wastes being discharged to Indiana watercourses.

Samples are filtered by means of a membrane filter and counts are made on the solids as well as the filtrate. At the same time, a chemical analysis is made of a portion of the same sample. Laboratory equipment consists of a proportional counter and a gas flow counting chamber which will hold a one inch planchet. An additional counting chamber, which will accommodate a two-inch planchet, is now on order.

Certain laboratory personnel and engineers are enrolled periodically in short courses for radiological instruction at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Indiana is also participating in the nationwide Radiation Surveillance program in cooperation with the Public Health Service and AEC. In addition, rain samples are collected and monitored in the State laboratory. A file is being maintained on all isotope users in the State. This list serves as a means of locating significant quantities of isotopes. Cooperation between users and the State Board of Health is essential to an effective radiological health program.

* * * * *

THE FEDERAL WATER POLLUTION CONTROL ACT

The new Federal Water Pollution Control Act (Public Law 660, 84th Congress) was approved by the President on July 9. A supplemental appropriation of $53 million to carry out various provisions of the legislation was approved on July 31.

The new statute:

1. Reaffirms the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the States in preventing and controlling water pollution.

2. Authorizes continued Federal-State cooperation in the development of comprehensive programs for the control of water pollution.

3. Authorizes increased technical assistance to States and a broadened program of research on water pollution.

4. Authorizes collection and dissemination of basic data on water quality relating to water pollution prevention and control.

5. Directs the Surgeon General to continue to encourage interstate compacts and uniform State laws.

6. Authorizes grants to States and interstate agencies up to $3,000,000 a year for the next 5 years for water pollution control activities.

7. Authorizes Federal grants of $50,000,000 a year (up to an aggregate of $500,000,000) for the construction of municipal sewage treatment works, the amount for any one project not to exceed 30 percent of cost or $250,000, whichever is smaller.

8. Modifies and simplifies procedures governing Federal abatement actions against interstate pollution.

9. Authorizes the appointment of a Water Pollution Control Advisory Board.

10. Authorizes a cooperative program to control pollution from Federal installations.

In approving the new legislation, the President pointed out that the provisions with respect to research, State program grants and control of interstate pollution "will help to further our national attack on water pollution in a manner that properly preserves the areas of Federal, State, and local responsibility."

With regard to the provision for grants for construction, the President urged "that no community with sufficient resources to construct a needed sewage treatment project without Federal aid, postpone that construction simply because of the prospect of a possible Federal grant. It should be clearly understood that Federal aid will not be available to all communities, and with respect to any one project, the Federal funds are limited in amount under the provisions of the bill."

The supplemental appropriation for the current fiscal year includes $50 million for construction grants. The portion which may be spent for this purpose in any one State or Territory must be computed on the basis of population and per capita income and their relation to the national population and per capita income.

Individual grants under the Act are limited to 30 percent of the estimated reasonable cost of the project of $250,000, whichever is less.

The Act requires that at least half of the funds appropriated for grants be used to assist construction of treatment works serving communities of 125,000 or under.

Federal and State Requirements

By the specific terms of the Act, six basic requirements must be met for a project to be eligible for Federal Construction Grant:

1. The project must be approved by the State Water Pollution Control Agency of the State in which the project is located.

2. It must conform to a State water pollution control plan submitted pursuant to the provisions of the Act.

3. It must be included in a comprehensive water pollution control program prepared or developed by the Public Health Service as required by the Act.

4. The applicant must agree to pay the remaining construction costs.

5. The applicant must make provision for insuring proper and efficient operation and maintenance of the project after construction.

6. The project must be certified by the State water pollution control agency of the State in which it is located as entitled to priority over other eligible projects on the basis of financial as well as water pollution control needs.

In determining whether a Federal grant should be made, the Surgeon General is required by the Act to give consideration to the public benefits to be derived from the project, the propriety of Federal aid in its construction, the relation of the ultimate costs of construction and maintenance to the public interest and public necessity and the adequacy of provisions made by the applicant for operation and maintenance.

The Supplemental Appropriation Act approved by the President on July 31 also contains an appropriation of $2,000,000 for program grants to States and interstate water pollution control agencies and $1,000,000 for administration of the various provisions of the Act.

Under the revised enforcement procedure, Federal court action to abate interstate pollution may be taken by the Government at the request either of the State in which the pollution originates or of the State affected by the pollution. Under the former Act, the consent of the upstream State was required.

The new Act also authorizes an intensified program of research, technical assistance and training. The Public Health Service's research facility at Cincinnati, the Robert A. Taft Sanitary Engineering Center, will be utilized for much of this phase of the program. Another new provision authorized the Service to develop research in universities and other non-Federal facilities on water pollution control by means of grants, contracts and fellowships.

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CERTIFICATION OF SANITARY ENGINEERS

The American Sanitary Engineering Intersociety Board, Inc. (ASEIB) has

received its first application for a certificate of special knowledge in sanitary engineering. In making this announcement Professor Boyce of the University of Michigan College of Engineering and chairman of the Board of Trustees of ASEIB said, "Receipt of this application marks the culmination of more than 5 years of planning and preparation. It also marks the beginning of the first program of certification of special engineering knowledge in any of the several engineering specialties."

The objective of the ASEIB is to improve the practice, elevate the standards and advance the cause of sanitary engineering. A means toward reaching this objective is the certification of those sanitary engineers who meet the criteria established by the ASEIB. All certified sanitary engineers will be carried on a roster to be known as the American Academy of Sanitary Engineering. The basic requirements for certification are registration as a professional engineer, graduation from a college of engineering and at least 8 years of sanitary engineering experience.

Eligibility for certification will be determined on the basis of the applicant's education, experience and an oral and written examination. Applicants with unusually high qualifications and at least 15 years of experience may be considered for certification without examination if the applications are filed before July 1, 1957. All applicants must pay an application fee of $10 plus a $25 examination fee.

The Intersociety Board is sponsored by the American Public Health Association, American Society of Civil Engineers, American Society of Engineering Education, American Water Works Association and Federation of Sewage Works Associations. The office of the Secretary of the Board, Mr. Francis B. Elder is located in the Engineering Societies Building, fifteenth floor, 33 West 29th St., New York 18, N. Y.

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SEWAGE DISPOSAL IN SUBDIVISIONS

An educational pamphlet on sanitary sewage disposal for subdivisions through small sewage treatment plants is being developed jointly by the Public Health Service and the National Association of Home Builders. Gathering of information and data from key areas that have experienced extensive fringe area construction problems has been under way in the East, Southeast, and Midwest.

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TRICKLING FILTER MEDIUM STUDIES

The Michigan Department of Public Health, the City of Battle Creek, Michigan and the Public Health Service are cooperating in a study of the effectiveness of a new plastic medium used in trickling filters for sewage treatment. The medium is very light in weight in comparison with conventional stone media. It can be used in very tall filters without the structural problems that would be involved in stone filters of comparable height.

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John M. Henderson (M.) was elected Vice-President and Lawrence C. Gray (J.M.) was appointed to the Program Committee of the Savannah Section of ASCE. At a recent meeting of the Savannah Section, Mr. John S. Wiley (M.) presented an illustrated talk on "Refuse Disposal, with Emphasis on Composting." All are staff members of the Communicable Disease Center, Technical Development Laboratories, Savannah, Georgia.

* * * * *

Case Institute of Technology is holding a one-day meeting on Statistical Methods for the Civil Engineer, on October 23, 1956. The meeting will consist of papers dealing with the use of statistics in various fields of civil engineering and will include such talks as, Data Handling, Statistics in Research, Use of Computing Machines, and Applied Statistics. They plan to have a luncheon and dinner, with the dinner speaker to be Rear Admiral Robert H. Meade, Chief, Bureau of Yards and Docks, of the United States Navy.

Anyone interested in attending this meeting can obtain further information by writing to Leon W. Weinberger, Associate Professor of Sanitary Engineering at Case Institute of Technology, University Circle, Cleveland 6, Ohio.

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FEDERAL SANITARY ENGINEERS ELECT NEW OFFICERS

The Conference of Federal Sanitary Engineers has elected the following officers for the year beginning June 1, 1956: Sanitary Engineer Director Gordon McCallum (USPHS), President, and Chairman of the Board; Assistant Surgeon General Mark D. Hollis (USPHS), President-Elect; and Lt. Col. Alvin F. Meyer, Jr. (USAF), Secretary-Treasurer. This is the Conference's first full slate of regular officers, the same individuals having served on a pro-tem basis since its formation about 14 months ago.

The new Board of Directors also includes the following nine elective members: San. Engr. Dir. Bernard Berger (USPHS); Lt. Col. Floy I. Berry (USA); Michael J. Blew (USA); Lt. Col. Jack C. Carmichael; San. Engr. Dir. Wesley E. Gilbertson (USPHS); San. Engr. Dir. Chris A. Hansen (USPHS); Burr Lenhart (USN); San. Engr. Dir. Harvey F. Ludwig (USPHS); and Lt. Col. John F. Pierce (USAF).

Purpose of the Conference is to bring together engineers engaged in the sanitary engineering profession, (including industrial hygiene), within the Federal government. Among specific aims are: support of the Joint Committee for the Advancement of Sanitary Engineering's American Sanitary Engineering Intersociety Board for certification of sanitary engineers; solution of mutual problems as training, recruitment, career planning and outside employment for U. S. Government engineers; and cooperation with existing technical and professional societies in the various functional areas of sanitary engineering designed for the promotion of public health. There are now about 300 members. Any sanitary engineer who is a commissioned officer of the military services or USPHS, or who is a civilian employee of any department or agency of the U. S. Government, is eligible for consideration for membership.

The first general meeting of the Conference was held in joint session with the Association of Military Surgeons of the U. S. last November in

Washington, D. C. Over 75 member-sanitary engineer representatives of nearly all Federal agencies in which sanitary engineers are employed attended. A breakfast session also was held at the APHA meeting in Kansas City last year. The next general meeting is scheduled for November 1956 in Washington, D. C.

Information on all CFSE activities may be obtained from the Secretary-Treasurer, Lt. Col. Alvin F. Meyer, 1502 South 94th Street, Omaha 6, Nebraska.

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NOTES ON UNIVERSITY RESEARCH

Cleveland industries and Case Institute of Technology have been contributing $50,000 a year to finance a research project on the industrial wastes problem in the Cleveland metropolitan area.

The study to date has been concerned with an evaluation of the industrial discharge to the municipal sewage treatment plants. Over 4,000 samples, mostly taken around the clock, from 22 sampling stations on interceptors were collected and analyzed. The analyses consisted of determinations for phenol, cyanide, copper, lead, chromium, manganese, nickel, and iron. Work is also underway by means of laboratory scale continuous flow units, to determine the effect of these elements on biological phases of sewage treatment.

The project at Case Institute of Technology is directed by George E. Barnes, Professor of Hydraulic and Sanitary Engineering, and Leon W. Weinberger, Associate Professor of Civil and Sanitary Engineering. Sponsors are American Steel & Wire, Harshaw Chemical Company, Jones & Laughlin, Republic Steel, Sherwin-Williams Company, Cleveland Electric Illuminating Company, Industrial Rayon Corporation, Standard Oil of Ohio, and Case Institute of Technology.

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LETTER TO THE EDITOR

Editors Note - From time to time your editor has written to members serving overseas asking for letters or brief articles commenting on the sanitary engineering activities in the countries in which they are working. The following letter is in reply to such a request. Professor Wilkie is due to return to his post at Purdue University early in the fall.

19 July 1956

Dear Paul: -

In Egypt today the ancient and the modern exist side by side. This fact was apparent immediately upon our arrival at Cairo's International Airport.

I observed the use of modern irrigation pumping equipment, but I also saw the centuries-old shadduf still being used by peasants to raise water by bucket from the canal to their fields. I had opportunity to visit modern water treatment plants—as well as opportunities to visit villages where the women carry clay water pots on their heads to fill the family water supply from the Nile or the canals.

In Egypt today the sanitary engineer must aid in bridging this gap between the old and the new. The reason for my assignment to Egypt by the World Health Organization was to help develop the training center in Alexandria for sanitary engineers throughout the Eastern Mediterranean area.

Sanitary engineering instruction in Egypt centers around the University of Alexandria and its cooperative program with the nearby High Institute of Public Health and the Sanitary Engineering Research Station now under construction.

Although the University of Alexandria was founded as recently as 1942, it draws from a long tradition of educational endeavor. During Alexandria's early history, after its founding by Alexander the Great in 342 B.C., the city was a world-renowned center of learning. Its famous library, the museum, and its scholarly activities under the Ptolemies are remembered in such works as those of Euclid, Elements of Geometry; Erathosthenes' measurement of the diameter of the earth; Claudius Ptolemy's studies in astronomy, developing the Ptolemaic theory that the universe revolves around the earth; Aristarchus' theory that the earth revolved around the sun; and the calculation of the period of a year for an accurate calendar.

With the decline of Rome the city passed through a decadent period. Virtually all of the great educational features of the city were destroyed, the nearby Canopic mouth of the Nile dried up, and Alexandria reverted to a small Mediterranean city. The Renaissance did not seem to take hold in Egypt—the easy-going life of the area seemed incapable of sparking and renewing the original greatness of Alexandria. It was not until World War II that the seeds of revival began to sprout and, like many areas of the world, industrialization, along with scientific interests, was superimposed upon the old way of life. Within the new nationalism in Egypt, an appreciation is being shown for the sanitation needs of the country along with the sanitary educational requirements to develop better public health facilities.

The civil engineering curriculum of the University of Alexandria places heavy emphasis on irrigation and structures. Consequently, a separate department for municipal and sanitary engineering is definitely needed here. The B.Sc. Degree in Municipal and Sanitary Engineering is awarded on the satisfactory completion of a 5-year technical curriculum.

A very rapid expansion of the municipal and sanitary engineering department is taking place at the present time. The World Health Organization is assisting in providing additional laboratory equipment and one visiting staff member. In addition, substantial help is being obtained from the U. S. Internation Cooperation Administration (Point IV).

Coupled with the University's Department of Municipal and Sanitary Engineering is a Sanitary Engineering Research Station now in the process of construction. Facilities are such that basic and applied research projects of particular importance to the Middle East can be undertaken.

Another feature of Alexandria's sanitary engineering educational activities is the High Institute of Public Health. Its first classes are expected to start in 1957. The Institute will offer advanced degree in public health—one division of which will be public health engineering.

In general, the philosophy supporting this development at Alexandria is that students in sanitary engineering should receive some of their university training within the culture of their own country or area in order to best serve the public health needs of that country.

This year's experience in Egypt has been an opportunity to observe

international public health activities, international and bilateral aid programs, and local attitudes concerning these inter-national activities.

And, incidentally, one of the "extras" was the opportunity to see such sanitary engineering textbook classics as London's Broad Street; the Paris sewers; the public baths, sewers, and aqueducts of ancient Rome; and, of course, the remains of the ancient water and irrigation systems of Egypt and the Middle East.

Best regards,

/s/ Harvey Wilkie

Please cooperate by sending news items of interest to:

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PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW) divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 861 is identified as 861 (SM1) which indicates that the paper is contained in issue 1 of the Journal of the Soil Mechanics and Foundations Division.

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OCTOBER: 809 (ST), 810 (HW)[c], 811 (ST), 812 (ST)[c], 813 (ST)[c], 814(EM), 815(EM), 816(EM), 817(EM), 818(EM), 819(EM)[c], 820(SA), 821(SA), 822(SA)[c], 823(HW), 824(HW).

NOVEMBER: 825(ST), 826(HY), 827(ST), 828(ST), 829(ST), 830(ST), 831(ST)[c], 832(CP), 833(CP), 834(CP), 835(CP)[c], 836(HY), 837(HY), 838(HY), 839(HY), 840(HY), 841(HY)[c].

DECEMBER: 842(SM), 843(SM)[c], 844(SU), 845(SU)[c], 846(SA), 847(SA), 848(SA)[c], 849(ST)[c], 850(ST), 851(ST), 852(ST), 853(ST), 854(CO), 855(CO), 856(CO)[c], 857(SU), 858(BD), 859(BD), 860(BD).

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JANUARY: 861(SM1), 862(SM1), 863(EM1), 864(SM1), 865(SM1), 866(SM1), 867(SM1), 868(HW1), 869(ST1), 870(EM1), 871(HW1), 872(HW1), 873(HW1), 874(HW1), 875(HW1), 876(EM1)[c], 877 (HW1)[c], 878(ST1)[c].

FEBRUARY: 879(CP1), 880(HY1), 881(HY1)[c], 882(HY1), 883(HY1), 884(IR1), 885(SA1), 886(CP1), 887(SA1), 888(SA1), 889(SA1), 890(SA1), 891(SA1), 892(SA1), 893(CP1), 894(CP1), 895(PO1) 896(PO1), 897(PO1), 898(PO1), 899(PO1), 900(PO1), 901(PO1), 902(AT1)[c], 903(IR1)[c], 904 (PO1)[c], 905(SA1)[c].

MARCH: 906(WW1), 907(WW1), 908(WW1), 909(WW1), 910(WW1), 911(WW1), 912(WW1), 913 (WW1)[c], 914(ST2), 915(ST2), 916(ST2), 917(ST2), 918(ST2), 919(ST2), 920(ST2), 921(SU1), 922(SU1), 923(SU1), 924(ST2)[c].

APRIL: 925(WW2), 926(WW2), 927(WW2), 928(SA2), 929(SA2), 930(SA2), 931(SA2), 932(SA2)[c], 933(SM2), 934(SM2), 935(WW2), 936(WW2), 937(WW2), 938(WW2), 939(WW2), 940(SM2), 941 (SM2), 942(SM2)[c], 943(EM2), 944(EM2), 945(EM2), 946(EM2)[c], 947(PO2), 948(PO2), 949(PO2), 950(PO2), 951(PO2), 952(PO2)[c], 953(HY2), 954(HY2), 955(HY2)[c], 956(HY2), 957(HY2), 958 (SA2), 959(PO2), 960(PO2).

MAY: 961(IR2), 962(IR2), 963(CP2), 964(CP2), 965(WW3), 966(WW3), 967(WW3), 968(WW3), 969 (WW3), 970(ST3), 971(ST3), 972(ST3)[c], 973(ST3), 974(ST3), 975(WW3), 976(WW3), 977(IR2), 978(AT2), 979(AT2), 980(AT2), 981(IR2), 982(IR2)[c], 983(HW2), 984(HW2), 985(HW2)[c], 986(ST3), 987(AT2), 988(CP2), 989(AT2).

JUNE: 990(PO3), 991(PO3), 992(PO3), 993(PO3), 994(PO3), 995(PO3), 996(PO3), 997(PO3), 998 (SA3), 999(SA3), 1000(SA3), 1001(SA3), 1002(SA3), 1003(SA3)[c], 1004(HY3), 1005(HY3), 1006 (HY3), 1007(HY3), 1008 (HY3), 1009 (HY3), 1010 (HY3)[c], 1011 (PO3)[c], 1012 (SA3), 1013 (SA3), 1014(SA3), 1015(HY3), 1016(SA3), 1017(PO3), 1018(PO3).

JULY: 1019(ST4), 1020(ST4), 1021(ST4), 1022(ST4), 1023 (ST4), 1024(ST4)[c], 1025(SM3), 1026 (SM3), 1027(SM3), 1028(SM3)[c], 1029(EM3), 1030(EM3), 1031(EM3), 1032(EM3), 1033(EM3)[c].

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SEPTEMBER: 1054(ST5), 1055(ST5), 1056(ST5), 1057(ST5), 1058(ST5), 1059(WW4), 1060(WW4), 1061(WW4), 1062(WW4), 1063(WW4), 1064(SU2), 1065(SU2), 1066(SU2)[c], 1067(ST5)[c], 1068 (WW4)[c], 1069(WW4).

OCTOBER: 1070(EM4), 1071(EM4), 1072(EM4), 1073(EM4), 1074(HW3), 1075(HW3), 1076(HW3), 1077(HY5), 1078(SA5), 1079(SM4), 1080(SM4), 1081(SM4), 1082(HY5), 1083(SA5), 1084(SA5), 1085(SA5), 1086(PO5), 1087(SA5), 1088(SA5), 1089(SA5), 1090(HW3), 1091(EM4)[c], 1092 (HY5)[c], 1093(HW3)[c], 1094(PO5)[c], 1095(SM4)[c].

c. Discussion of several papers, grouped by Divisions.